APPENDIX C

Drill Waste Dispersion Modelling

UpstreamHSE

Technical Report

Scotian Basin Exploration Drilling Project: Well NS-1 – Drilling mud and cuttings dispersion modelling

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Contents

Executive Summary

This report presents the results of modelling the theoretical dispersion of drilling muds and cuttings released while conducting an exploration drilling program on Exploration Licences (ELs) 2431, 2432, 2433, and 2434, known as the Scotian Basin Exploration Drilling Project (SBEDP). The modelling was conducted using the SINTEF Marine Environmental Modelling Workbench (MEMW) software, which includes the numeric Dose-related Risk and Effects Assessment Model (DREAM) for chemical releases and Particle Tracking model for drilling discharges (ParTrack).

The main purpose of the modelling was to generate results leading to the development and validation of statements on environmental impact assessment for inclusion in the Environmental Assessment for the Project. The model set-up and scenarios were based on the current base case 5-string well and fluids design for the first exploration well. The time to drill the well (up to 120 days) was estimated for the success case which assumes the well will be drilled from spud to TD, with an extensive logging programme within each hole section. The well will initially be drilled with sea water gel sweeps and water based mud (WBM), prior to be being displaced to a Non-aqueous Fluid (NAF) to drill the lower reservoir sections. Once wells have been drilled to TD and well evaluation programs completed, the well will be plugged and abandoned in line with applicable BP practices and CNSOPB requirements.

A total of 8 separate drilling and batch releases will occur while drilling the exploration well. An Excel mass balance model was developed to calculate the total volume and tonnage of drill cuttings, water based mud and NAF discharged to sea. Of the well designs currently being considered, the design with the largest overall casing/hole volume was used in the modelling, to ensure the worst credible discharge of cuttings was considered in assessing the environmental impact of the drilling discharges. Similarly, to make sure the worst case scenario was used in modelling the discharge of mud and cuttings from the sections drilled with NAFs, it was assumed that a synthetic based fluid (SBF) would be used in conjunction with cuttings dryers to achieve an acceptable oil retention of 6.9% oil on cuttings by wet weight of base fluid on cuttings, before discharging the residue to sea.

Final well locations have not yet been identified so for the purposes of this study two location scenarios were considered representing the shallowest (2,104 m) and deepest (2,790 m) water depths. For each location, model simulations of 100 day durations were carried out assuming a 1st July spud date.

The 3-D current hindcast dataset used in DREAM modelling to drive drill cutting dispersion and pollutant transport was comprised of daily HYCOM current speeds with Bedford Institute Tides linearly superimposed interpolated onto a three hourly time step for the period 1st January 2006 and 31st December. In addition, a 2-D wind field dataset covering the same time period was generated from the National Centre for Atmospheric Research (NCAR) / National Centre for Environmental Protection (NCEP) Climate Forecast System Reanalysis (CFSR).

At both sites, although around 50% by weight of the mud and cuttings released was transported outside the boundaries of the modelling domain, any drill solids deposited on the sea-floor were at insignificant thicknesses of less than 0.001mm (1 micron).

At Site 1 (shallowest water depth scenario), the predicted deposition footprint was predominantly towards the East and North East for the surface discharges, whereas at Site 3 (deepest water depth scenario) it was predominantly towards the South West and extends over a greater area (by 10 – 15%) than for the shallow water depth well location for thickness thresholds < 0.5 mm, as the increased water depth means that finer drill solids released in the surface discharges are transported over a greater distance before settling, with a reduced thickness and concentration of cuttings nearer the release location.

For example, at a deposit thickness threshold of 1 micron, the drilling discharge deposits covered an area of 5,350 hectares at Site 3 compared to 4,870 hectares at Site 1. In contrast, nearer the release site at Site 3 the predicted thickness of deposited drill solids > 1 mm ("visible" thickness threshold), extends circa 360 m from the discharge point in a South Westerly direction at its maximum extent and covers 4.2 hectares. This is less than half the area coverage at Site 1, where the 1 mm thickness boundary extends 560 m from the discharge point.

At deposition thicknesses of approximately 10 mm or more, benthic communities comprised of sedentary or slow moving species, may be smothered and the sediment quality will be altered in terms of nutrient enrichment and oxygen depletion.

Using an average burial depth of 9.6 mm as a minimum threshold where we would expect to see adverse effects to benthic organisms (Neff et al. 2004 [(14)]), then the modelling results predict that at Site 1 these sediment thicknesses could extend approximately 78 m from the discharge point, or cover an area of approximately 0.54 hectares per well. A similar coverage area was predicted at Site 3 but with a slightly longer maximum extension from the discharge point (116 m). Thicknesses of 100 mm or greater are confined to distances of 20 m - 30 m from the discharge site with aerial extents of 0.07 hectares. Analysing the contribution to sediment footprint and thickness from the mud and cuttings generated from each hole section demonstrated that the predicted deposition footprint of discharges generated from the first two 'top hole' riserless sections (discharged directly onto the seabed), is localised around the wellhead location, whereas material from subsequent hole sections discharged at the sea surface were spread over a much larger area.

1 Introduction

BP Canada Energy Group ULC is proposing to conduct an exploration drilling program on Exploration Licences (ELs) 2431, 2432, 2433, and 2434, known as the Scotian Basin Exploration Drilling Project (SBEDP). BP holds a 40% interest in the Nova Scotia Offshore ELs and will operate the exploration program. Partners Hess Canada Oil and Gas ULC and Woodside Energy International (Canada) Limited hold a 40% and 20% interest, respectively. (see Figure 1.1)

BP proposes to drill up to seven wells on the aforementioned Exploration Licenses which cover 13,982 km2 and are located approximately 230 to 370 km southeast of Halifax and 48 km from Sable Island National Park Reserve. Sable Island is also the nearest permanent, seasonal or temporary residence to the Project Area except for workers inhabiting offshore platforms at the Sable Offshore Energy Project and the Deep Panuke developments. Water depths in the licences range from 100 metres (m) to more than 3,000 m. Several major currents, including the Labrador Current and Gulf Stream, influence the circulation in the region.

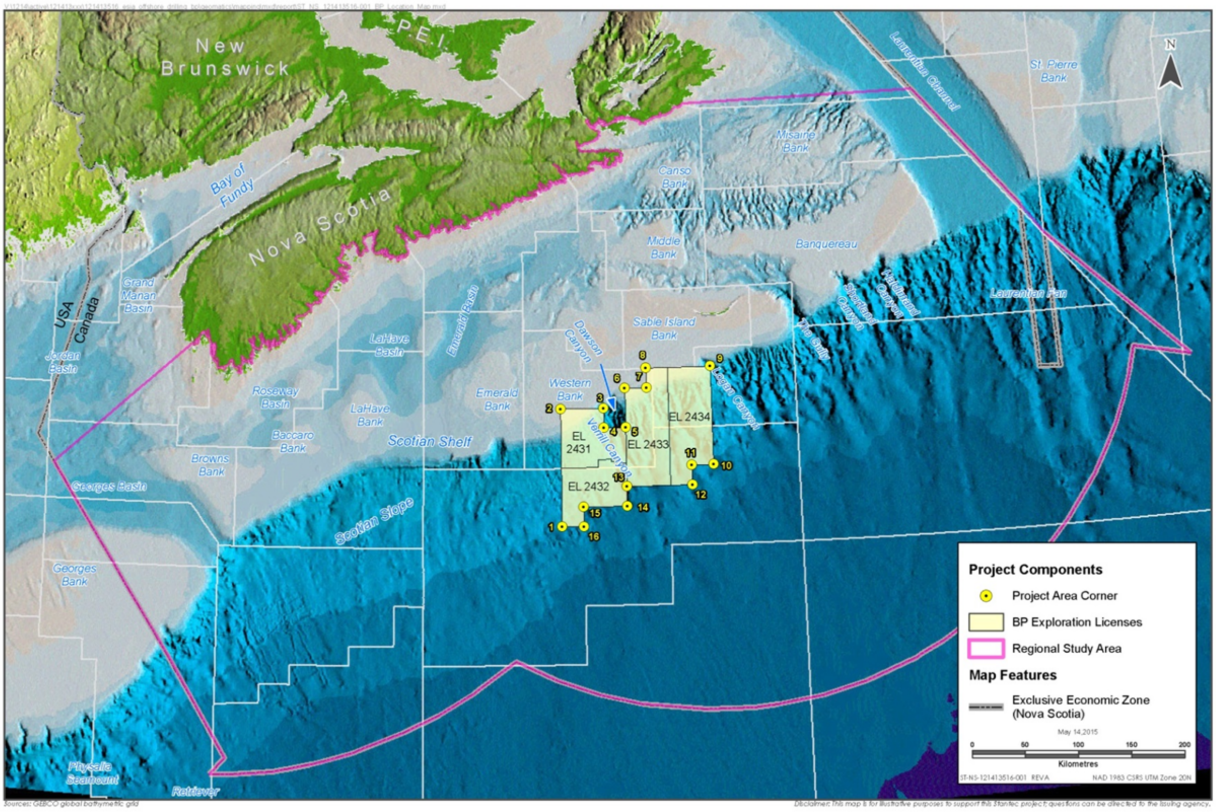


Figure 1.1 Scotian Basin Exploration Drilling Project Location

1.1 Scope of Work

The main purpose of the modelling was to generate results leading to the development and validation of statements on the potential environmental impact of mud and cuttings suspensions and sediment deposition resulting from the operational release of drilling discharges during offshore drilling for inclusion in the Environmental Assessment for the Project. The draft Environmental Impact Statement guidelines [(1)] issued by the Canadian Environmental Assessment Agency states that:

> *"Disposal of drilling waste (i.e., cuttings) is expected to be a primary cause of effects to marine benthos. The EIS should indicate the areal extent of drilling waste deposition at various water depths and at various stages of drilling, including during riserless drilling and drilling with the marine riser in place, using dispersion modelling."*

Dispersion modelling of the release of drilling muds and cuttings from the SBEDP was conducted using the SINTEF Marine Environmental Modelling Workbench (MEMW) software, which includes the numeric Dose-related Risk and Effects Assessment Model (DREAM) for chemical releases and Particle Tracking model for drilling discharges (ParTrack).

2 Drilling Program

BP has not yet selected the MODU that will be used to drill the wells in the Scotian Basin. In consideration of the water depths in the ELs (up to approximately 3,000 m), it is expected that either a semi-submersible rig or a drillship will be used.

The standard mooring technique for a semi-submersible is an eight point spread mooring arrangement using a combination of wire rope, chains, and anchors. The anchors are set in a pre-determined pattern using an anchor handling offshore vessel.

In the DP mode, a semi-submersible or drillship maintains position using thrusters positioned on the hulls, which are controlled by a computerized positioning system.

Prior to drilling, the proposed wellsite location will be surveyed using a remotely operated vehicle (ROV) to inspect the seabed for potential hazards and sensitive habitat (e.g., habitat-forming corals).

The well design has not been finalised. However, it is anticipated that that the first two sections of the well (conductor hole and surface hole) will be drilled riserless with a water-based mud (WBM), with mud and cuttings returned to the seabed where they will accumulate in the vicinity of the wellhead. The discharge of WBM cuttings at the seabed, while drilling the first two hole sections is accepted as industry standard practice and is consistent with the Offshore Waste Treatment Guidelines (OWTG) (NEB *et al.* 2010 [(2)]). Once a riser system has been installed, the deeper (lower) hole sections of the well will be drilled using a recirculating drilling fluid system. The marine riser run between the Blowout Preventer (BOP) and the drilling vessel will provide a conduit for the return of drilling fluid and cuttings back to the drilling vessel. WBM and/or synthetic-based mud (SBM) will be used for these hole sections.

On the drilling vessel the drilled cuttings and drilling fluid will be separated and cleaned using solids control equipment. The mud returns carrying the drilled cuttings will initially pass through a shale shaker where the majority of mud will be separated from the cuttings. Where SBM is used; cuttings from the shale shaker will be passed through a cuttings dryer, which will remove SBM from cuttings. Residual synthetic base fluid on cuttings discharged to the marine environment will not exceed 6.9 g/100 g oil on wet solids (48-hour mass weighted average) in accordance with the OWTG. Monitoring of the residual base fluid on cuttings levels will be carried out during hole sections involving use of SBM. After recovery of drill fluids and confirmation of treatment success, the drill cuttings will be discharged from the drilling vessel at the well site. Spent and excess WBM may be discharged from the drilling vessel without treatment as per the OWTG. No whole SBM will be discharged to the sea; spent SBM that cannot be reused during drilling will be brought to shore for disposal.

BP proposes to drill a single well in 2017. Depending on the results of the initial well, up to a total of seven wells may be drilled over a four year period. It is anticipated that it will take up to 130 days to drill each well.

3 DREAM (Dose related Risk and Effect Assessment Model)

3.1 Model Background

The numerical model DREAM (Dose related Risk and Effect Assessment Model) has been developed at SINTEF with support from StatoilHydro, ENI, Total, ExxonMobil, Petrobras, ConocoPhillips, Shell, and British Petroleum. The model is a decision support tool for management of operational discharges to the marine environment. DREAM is integrated with the oil spill model OSCAR within a graphical user interface called the Marine Environmental Modelling Workbench (MEMW). The system has been in continuous development for the past 15 years with a drilling discharge capability added to the system. DREAM is a 3-dimensional, time-dependent, multiple-chemical transport, exposure, dose, and effects assessment model. DREAM can account simultaneously for up to 200 chemical components, with different release profiles for 50 or more different sources (Reed et.al. [(3, 4)]). Each chemical component in the effluent mixture is described by a set of physical, chemical, and toxicological parameters. Because petroleum hydrocarbons constitute a significant fraction of many industrial releases, DREAM incorporates a complete surface slick model, in addition to the processes governing pollutant behaviour and fates in the water column.

3.2 General model description

DREAM is a software tool designed to support rational management of environmental risks associated with operational discharges of complex mixtures. The model has been evolved over a number of years (Reed et al.[(3,4)]; Johnsen et al. [(5)] ; Rye et al. [(6,7)]). Governing physical-chemical processes are accounted for separately for each chemical in the mixture, including:

- vertical and horizontal dilution and transport,
- dissolution from droplet form,
- volatilization from the dissolved or surface phase,
- particulate adsorption/desorption and settling,
- bio-degradation,
- sedimentation to the sea floor.

The algorithms used in the computations, and verification tests of the resulting code, are presented in Reed et al. [(2)]. The model has also been verified against field measurements (Neff et al [(8)]; Durrell et al. [(9)]).

Chemical concentrations in the water column are computed from the time- and space-variable distribution of pseudo-Lagrangian particles. These particles are of two types, those representing dissolved substances, and those representing droplets composed of less soluble chemical components or solid particulate matter in the release. These latter particles are pseudo-Lagrangian in that they do not necessarily move strictly with the currents, but may rise or settle according to their physical characteristics.

Each mathematical particle represents conceptually a Gaussian cloud (or “puff”) of dissolved chemicals, droplets, or sinking particles). Concentration fields are built up in the model from the superposition of all of these clouds of contaminants. Each cloud consists of an ellipsoid with a particle at its centre, and semi-axes a function of the time-history of the particle. (Ellipsoids encountering boundaries are truncated, with mass being conserved through reflection from the boundary, sorption to the boundary, or some combination of the two.) Particles representing dissolved substances carry with them the following attributes:

- x, y, and z spatial coordinates,
- mass of each chemical constituent represented by the particle,
- distance to and identity of the nearest neighbour particle,
- time since release,
- spatial standard deviations in x, y, and z.

Particles representing non-dissolved substances, such as oil droplets, drill muds or cuttings, carry two additional attributes:

- mean droplet diameter,
- droplet density.

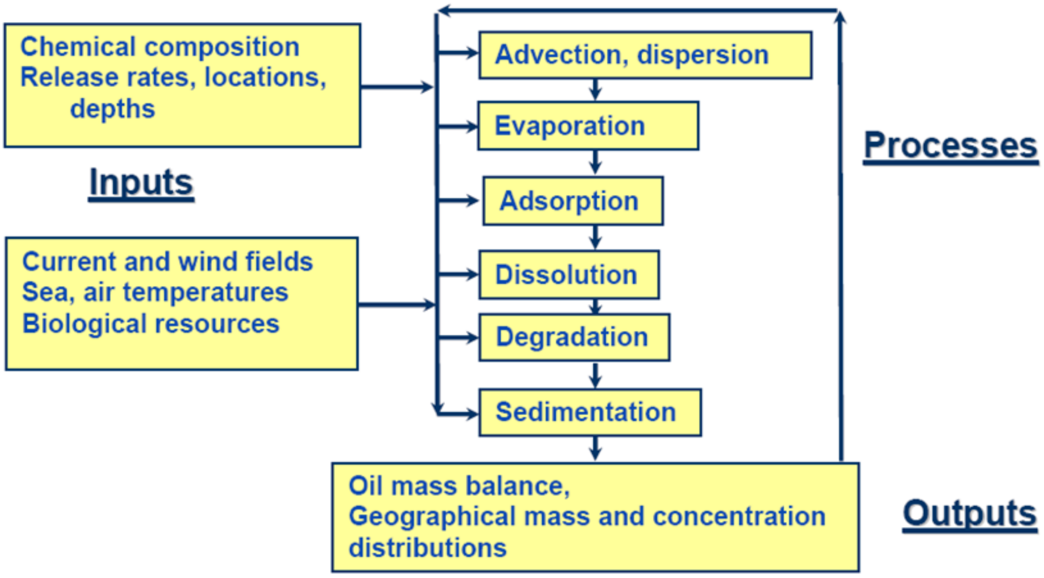
Concentrations are computed within one of three user-specified three-dimensional grid systems. The first is a translating, expanding grid that follows the evolution of a release, thus providing higher resolution during the early stages and lower resolution as time progresses. The second is a fixed grid, with resolution defined by the user. The third is a grid with fixed horizontal resolution, but time-variable vertical resolution. This latter grid is useful, for example, in resolving surface releases of oil, in which the near-surface vertical evolution may be of particular interest.

As mentioned earlier, the position of each particle locates the centre of a moving, spreading ellipsoidal cloud, with axes a function of the time-history of the particle. The theoretical distribution of mass within the ellipsoid is assumed Gaussian. Each such ellipsoid will typically contribute mass to many cells in the concentration field, and neighbouring ellipsoids will typically overlap spatially. Thus a given cell in the concentration field will in general contain a concentration resulting from the presence of multiple nearby particle clouds. This hybrid numerical – analytic scheme removes much of the dependence of the computed concentration field on both the number of particles and the resolution of the physical 3-dimensional grid.

The model is driven by winds and currents either produced by other numerical models, or measured as time series in the region of interest. Global datasets of bathymetry and coastlines are supplied with the system, and can be augmented by the user via standard GIS and/or ASCII formats.

Processes governing the behaviour of pollutants in DREAM are presented in Figure 3.1

Figure 3.1 General Schematic of the DREAM Model



DREAM employs surface oil spill model algorithms to simulate the behaviour and fates of surface slicks. Such slicks can occur in the model as the result of rising oil drop released at the air-water interface. In the water column, horizontal and vertical advection and dispersion of entrained and dissolved hydrocarbons are simulated by random walk procedures. Vertical turbulence is a function of wind speed (wave height) and depth; horizontal turbulence is a function of the age of a pollutant 'cloud'. Pollutants near the sea surface may evaporate to the atmosphere. Partitioning between particulate-adsorbed and dissolved states is calculated based on linear equilibrium theory. The contaminant fraction that is adsorbed to suspended particulate matter settles with ambient particles. Contaminants at the bottom are mixed into the underlying sediments, and may dissolve back into the water. Degradation in water and sediments is represented as a first order decay process, with the possibility of producing intermediate metabolites. Results of model simulations are stored at discrete time-steps in data files for subsequent viewing and analysis.

For spilled oil, processes such as advection, spreading, entrainment and vertical mixing in the water column are not directly dependent on oil composition, although all tend to be linked through macro-characteristics such as viscosity and density. Other processes, such as evaporation, dissolution, and degradation are directly dependent on oil composition.

DREAM focuses primarily on underwater releases, such that surface phenomena are of secondary interest. Oil droplets contained in produced water, for example, may rise to the surface and form a surface slick, such that related processes must also be represented in the model. DREAM uses the same algorithms for these processes as used in the oil spill contingency and response model OSCAR. These algorithms are described in detail in Reed et al. [(4)]. The DeepBlow model (Johansen[(5)]), developed in response to the interest in petroleum exploration in deep waters, has been generalized and serves as the 3-dimensional dynamic near field module for DREAM as well as for the oil spill model OSCAR. DeepBlow is a Lagrangian element model, the plume being represented by sequence elements. Each element, which can be thought of as a conical cylindrical section of a bent cone, is characterized by its mass, location, width (radius), length (thickness), average velocity, pollutant concentrations, temperature and salinity. These parameters will change as the element moves along the trajectory, i.e. the element increases in mass due to shear-induced and forced entrainment, while rising or sinking according to buoyancy and becoming sheared over by the cross flow. This modified version, called Plume-3D, functions as a near-field module for produced water and drilling discharges, as well as other releases of complex mixtures in an aquatic environment. This module is activated automatically whenever a release is specified to originate under water. Depending on depth and other input parameters, the module automatically computes the near-field plume, and the release of dissolved, solid, and droplet-related pollutants from the plume and into the far field.

4 Model Setup and Input Data

The model set-up and scenarios were based on the current base case 5-string well and fluids design for the first exploration well. Designs for Project wells have not yet been finalized. However, an indicative well design for the Project wells is presented in Table 4.1 below and will be drilled in line with the principles set out in Section 2.

The time to drill the well (120 days) was estimated for the success case which assumes the well will be drilled from spud to TD, with an extensive logging programme within each hole section. It is not currently anticipated that well testing will be carried out on the first two wells drilled as part of the Project. Once wells have been drilled to TD and well evaluation programs completed, the well will be plugged and abandoned in line with applicable BP practices and CNSOPB requirements.

MEMW version 7.0 was used to carry out the modelling.

4.1 Drilling Data

Final well locations have not yet been identified so for the purposes of this study two location scenarios were considered representing the shallowest and deepest water depths (Figure 4.1). Both locations represent viable drilling prospects.

1. **Shallow water depth well (Site 1):**

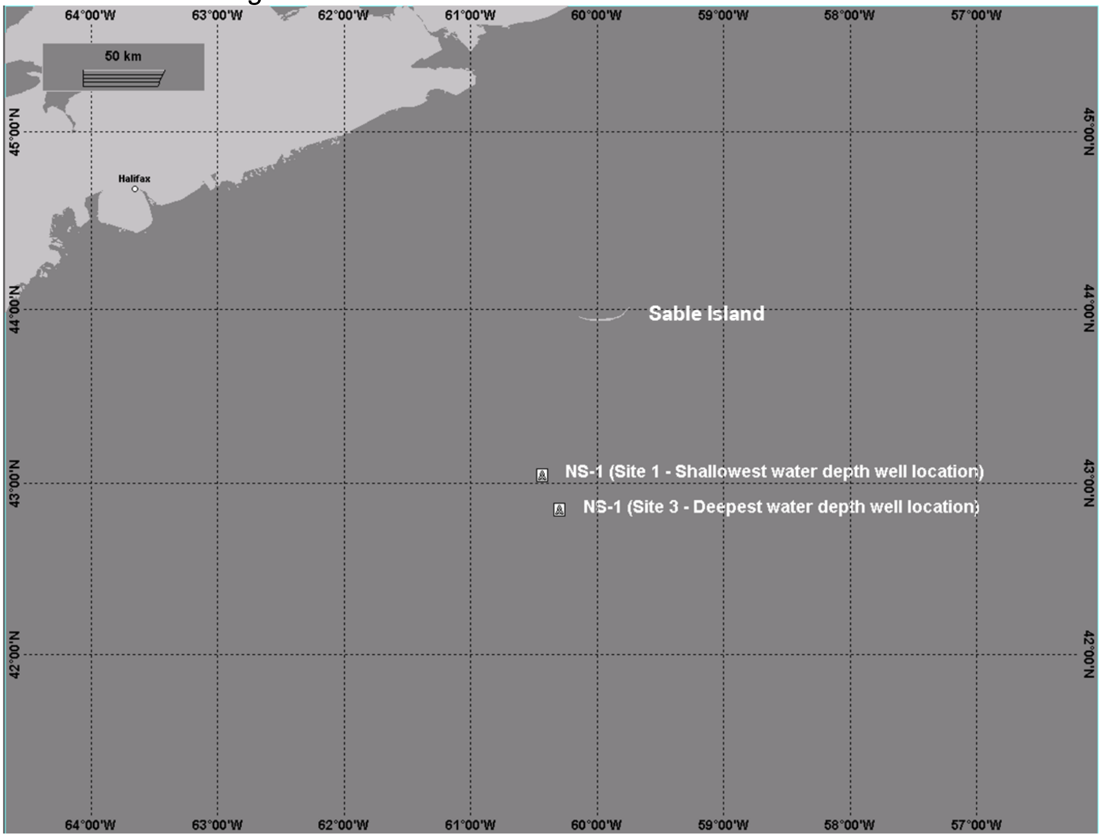
Latitude	43° 2' 47.1408" N
Longitude	60° 26' 4.596" W
Water depth	2,104 m

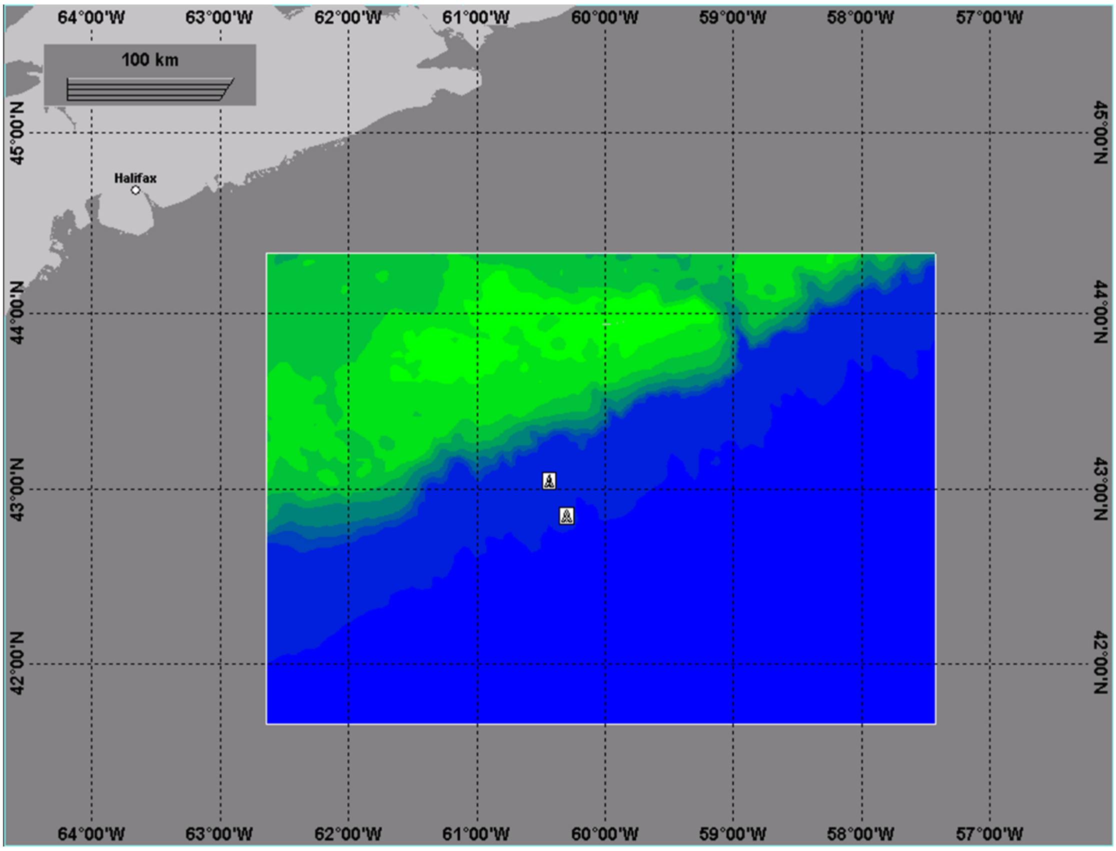
2. **Deep water depth well scenario (Site 3):**

Latitude	42° 50' 49.6104" N
Longitude	60° 17' 51.3996" W
Water depth	2,790 m

For each location, model simulations of 100 day durations were carried out assuming a 1st July spud date. The plan is to drill the first two hole sections (36" x 42" and 26" hole) riserless using seawater and Guar Gum sweeps and to displace the hole to weighted viscous pre-hydrated gel fluid before running the casing. All the mud and cuttings generated will be discharged at the seafloor. The remaining four hole sections to TD (17" x 20", 14 ¾" x 17 ½", 10 5/8" x 12 1/4" and 8 ½") will be drilled with a NAF. A total of 8 separate drilling and batch releases will occur while drilling the exploration well.

Figure 4.1 Potential locations of NS-1 exploration well selected for cuttings dispersion modelling





An Excel mass balance model was developed to calculate the total volume and tonnage of drill cuttings, water based mud and SBM discharged to sea using the well and casing design information and mud dilution factor data inputs presented in Table 4.2. Typical generic mud formulations for each hole section were then used to calculate the tonnage of each chemical component discharged to sea as shown in Appendix 1, Tables A1 – A6.

The average rate of penetration for each hole section and the time interval between drilling discharges was calculated using time estimates of drilling and completion activities for the well as shown in Table 4.3. Estimates of the amounts and types of drilling discharges expected are shown in Table 4.4 and Figure 4.2.

Modelling was conducted for all 8 drilling operational releases. Of the well designs currently being considered, the design with the largest overall casing/hole volume was used in the modelling, to ensure the worst case volume discharge of cuttings was considered in assessing the environmental impact of the drilling discharges. Similarly, to make sure the worst case scenario was used in modelling the discharge of mud and cuttings from the sections drilled with NAFs, it was assumed that a SBM would be used in conjunction with cuttings dryers to achieve an acceptable oil retention of 6.9% oil on cuttings by wet weight of base fluid on cuttings, before discharging the residue to sea.

The particle size distribution of particulates (barite, drill cuttings, bentonite etc.) in the drilling discharges used in the modelling are presented in Figure 4.3.

Table 4.1 Indicative Well Casing Plan for Project Wells

DATA INPUT SHEET

Nova Scotia NS1 Offshore Exploration Well - DEPTHS AND CASING POINTS

TYPICAL 6-STRING WELL

Number of 5 String Wells	1				Interval Length (m)	Casing Depth (m bml)	Section Measured Depth (m brt)	Total Metres Drilled by Hole Size (m)
Water Depth (m)							2,650	
Interval	Casing Size (ins)	Casing ID (ins)	Bit Diameter (ins)	Overguage Hole Diameter (ins)				
36" x 42"- Sea Water & Gel Sweeps & PAD Mud	36 " @	34.00	42.00	47.00	100	100	2,750	100
26" Sea Water & Gel Sweeps & PAD Mud	22" @	20.50	26.00	30.00	800	900	3,550	800
17" x 20" SBM	16" @	14.85	20.00	21.50	950	1,850	4,500	950
14 3/4" x 17 1/2" SBM	14" @	12.40	17.50	18.50	1,100	2,950	5,600	1,100
10 5/8" x 12 1/4" SBM	9-5/8"@	8.50	12.25	13.00	2,250	5,200	7,850	2,250
8 1/2" SBM			8.50	9.00	250	5,450	8,100	250

Number of 5 String Wells	1				Interval Length (ft)	Casing Depth (ft bml)	Section Measured Depth (ft brt)	Total footage drilled by Hole Size (ft)
Water Depth (ft)							8,694	
Interval	Casing Size (ins)	Casing ID (ins)	Bit Diameter (ins)	Overguage Hole Diameter (ins)				
36" x 42"- Sea Water & Gel Sweeps & PAD Mud	36 " @	34.00	42.00	47.00	328	328	9,022	328
26" Sea Water & Gel Sweeps & PAD Mud	22" @	20.5	26.00	30.00	2,625	2,953	11,647	2,625
17" x 20" SBM	16" @	14.85	20.00	21.50	3,117	6,069	14,764	3,117
14 3/4" x 17 1/2" SBM	14" @	12.4	17.50	18.50	3,609	9,678	18,372	3,609
10 5/8" x 12 1/4" SBM	9-5/8"@	8.5	12.25	13.00	7,382	17,060	25,754	7,382
8 1/2" SBM			8.50	9.00	820	17,880	26,574	820

Table 4.2 Drilling fluid assumptions for NS-1 exploration well

ASSUMPTIONS

1. Hole Washout, Cuttings SG and Release Point Information

Interval	Percent Overgauge	% Volume Washout	Cuttings SG	Discharge Depth (m)		Discharge Temperature at Release Point (deg C)	Diameter of outlet opening (m)	Orientation of outlet opening
				Above sea-floor	Below sea surface			
36" x 42"- Sea Water & Gel Sweeps & PAD Mud	12%	25%	2.0	1.0	-	18.0	-	Vertical, up
26" Sea Water & Gel Sweeps & PAD Mud	15%	33%	2.1	1.0	-	18.0	-	Vertical, up
17" x 20" SBM	8%	16%	2.2	-	15	18.0	0.50	Vertical , down
14 3/4" x 17 1/2" SBM	6%	12%	2.3	-	15	18.0	0.50	Vertical , down
10 5/8" x 12 1/4" SBM	6%	13%	2.4	-	15	18.0	0.50	Vertical , down
8 1/2" SBM	6%	12%	2.5	-	15	18.0	0.25	Vertical , down

2. Hole Displacement Excess (Riserless Sections)

Interval	Pill Volume (bbls)	Frequency (Every x ft)	Safety Margin (%)
26" x 42" - Hi Vis Sweeps	100	45	20%
26" - Hi Vis Sweeps	100	45	20%

PAD Mud Displacement Criteria

Interval	Surface Volume (bbls)	# x OH Vol	# x CSG Vol	# of PAD Displacements
26" x 42" - PAD Mud	700	2	1	2
26" - PAD Mud	700	2	1	2

3. Fluid Densities and NAF Composition

Average Fluid Densities			NAF Composition				
Interval	Max Mud SG	Max Mud Weight ppg	O/W ratio		Solids	Oil	Water
26" x 42" - Hi Vis Sweeps	1.05	8.76	n/a	n/a	n/a	n/a	n/a
26" x 42" - PAD Mud	1.26	10.50	n/a	n/a	n/a	n/a	n/a
26" - Hi Vis Sweeps	1.05	8.76	n/a	n/a	n/a	n/a	n/a
26" - PAD Mud	1.35	11.30	n/a	n/a	n/a	n/a	n/a
17" x 20" SBM	1.27	10.60	75	25	6.8%	69.9%	23.3%
14 3/4" x 17 1/2" SBM	1.53	12.73	75	25	5.3%	71.0%	23.7%
10 5/8" x 12 1/4" SBM	1.79	14.90	75	25	5.3%	71.0%	23.7%
8 1/2" SBM	1.89	15.79	75	25	9.3%	68.0%	22.7%
Base oil	0.79	6.58					

4. Mud Dilution Factors

Interval	bbl/ft	bbl/m
17" x 20" SBM	0.1450	0.48
14 3/4" x 17 1/2" SBM	0.1150	0.38
10 5/8" x 12 1/4" SBM	0.0610	0.20
8 1/2" SBM	0.0330	0.11

Table 4.3 Activity time estimates associated with drilling and completion operations for NS-1 exploration well

Project Name	**Nova Scotia NS1 Offshore Exploration Well**

Well Type 1	5-string Exploration Well

D&C Sequence #	**Operation**	**Total Days**	**Cumulative Days**	**Cumulative Days Post Spud**	**Average ROP (m/hr)**	**Start of Discharge (time since end of last discharge)**	
						(hrs)	**(days**
1	Rig Move	4.2	4.2				
2	Run Achor	6.5	10.6				
3	Pre-Spud works	2.6	13.3				
4	Drill 26" x 42" hole	2.9	16.2	2.9	1.4	0.0	0.0
5	Run & Cement 36" Conductor	2.2	18.4	5.1			
6	Drill 26" hole	2.7	21.1	7.8	7.5	28.8	1.2
7	Cont. Drill 26" hole to section TD	1.8	22.8	9.6			
8	Run 22" casing/WH & cement	4.6	27.4	14.1			
9	Run BOP and riser	7.5	34.9	21.7			
10	Drill 17" x 20" hole to section TD	4.1	39.1	25.8	9.6	266.6	11.1
11	Run W/L log (Assume : 5 run max)	6.6	45.7	32.4			
12	Run & Cement 16"" Liner	3.8	49.5	36.2			
13	Drill 14 3/4" x 17 1/2" hole to section TD	6.6	56.0	42.8	7.0	249.8	10.4
14	Run W/L log (Assume : 5 run max)	2.5	58.5	45.2			
15	Run & cement 14" casing	4.9	63.4	50.1			
16	Drill 12 1/4 " to section TD	18.0	81.4	68.1	5.2	176.1	7.3
17	Run W/L Log	4.2	85.6	72.3			
18	Run & set 9 5/8" liner	6.2	91.8	78.6			
19	Drill 8 1/2" hole to section TD	12.4	104.2	90.9	0.8	251.3	10.5
20	Run W/L log (Assume : 5 run max)	3.8	108.0	94.8			
21	P&A/Pull Riser & BOP/ Rig Achoring Ops.	12.0	120.0	106.7			

Table 4.4 Quantitative estimate of the amounts and types of drilling discharges expected from drilling the NS-1 exploration well

Nova Scotia NS1 Offshore Exploration Well

DISCHARGES BY HOLE SECTION PER WELL	Discharges While Drilling					Batch Discharge of WBM Mud at End of Sections			
						Emptying of Sand traps		Whole mud displacement	
Hole Section / Mud Type	Total Footage Drilled	Cuttings Discharge (tonnes)	Mud Discharge (tonnes)	Chemicals* discharged (tonnes)	Oil Discharge (tonnes)	Mud Discharge (tonnes)	Chemicals discharged (tonnes)	Mud Discharge (tonnes)	Chemicals *discharged (tonnes)
36" x 42"- Sea Water & Gel Sweeps & PAD Mud	328	224	146	2	0	n/a	n/a	703	193
26" Sea Water & Gel Sweeps & PAD Mud	2,625	766	1,168	19	0	n/a	n/a	2,184	772
17" x 20" SBM	3,117	490	91	77	40	n/a	n/a	n/a	n/a
14 3/4" x 17 1/2" SBM	3,609	439	101	89	37	n/a	n/a	n/a	n/a
10 5/8" x 12 1/4" SBM	7,382	462	128	116	40	n/a	n/a	n/a	n/a
8 1/2" SBM	820	26	8.14	7.46	2	n/a	n/a	n/a	n/a
Total	**17,880**	**2,406**	**1,642**	**311**	**119**	**0**	**0**	**2,887**	**965**

* Chemicals includes commercial solids (barite bentonite etc.) added to the mud system

TOTAL DISCHARGES PER WELL

Waste Category	Discharges by Volume		Discharges by Weight
Total Cuttings discharged to sea while drilling	6,874 bbls	1,093 m^3	**2,406 tonnes**
Total WBM discharged to sea while drilling	7,874 bbls	1,252 m^3	**1,314 tonnes**
Total Batch discharge of WBM to sea	10,146 bbls	1,613 m^3	**2,887 tonnes**
Total SBM discharged to sea while drilling	1,344 bbls	214 m^3	**328 tonnes**
Total Drilling Chemicals Discharged to Sea			**1,276 tonnes**
Note:			
Discharges of Synthetic Base Oil included within the SBM discharge amount to:	949 bbls	151 m^3	**119 tonnes**

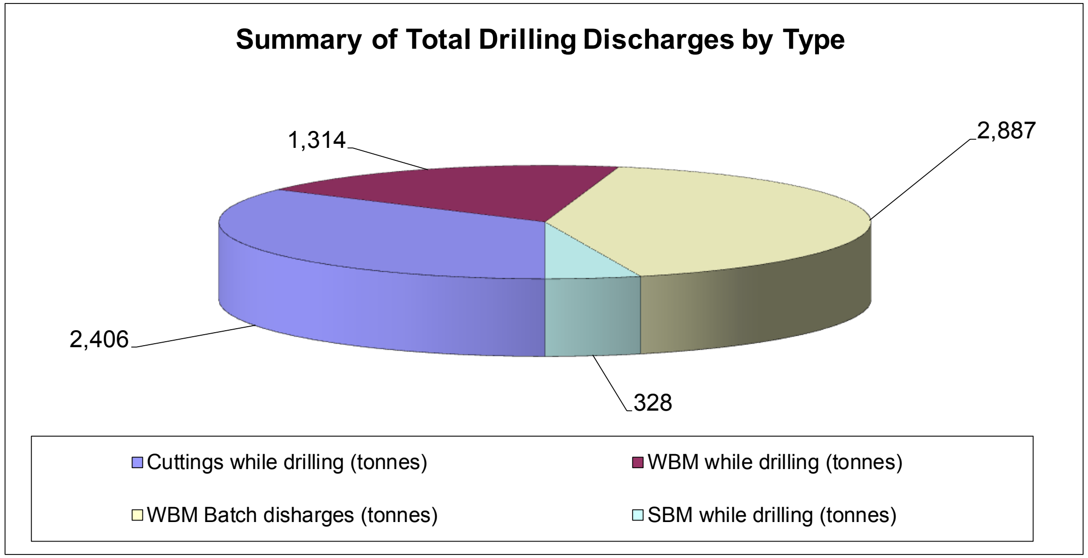


Figure 4.2 Average discharge rates to water of mud and cuttings components over the duration of the well

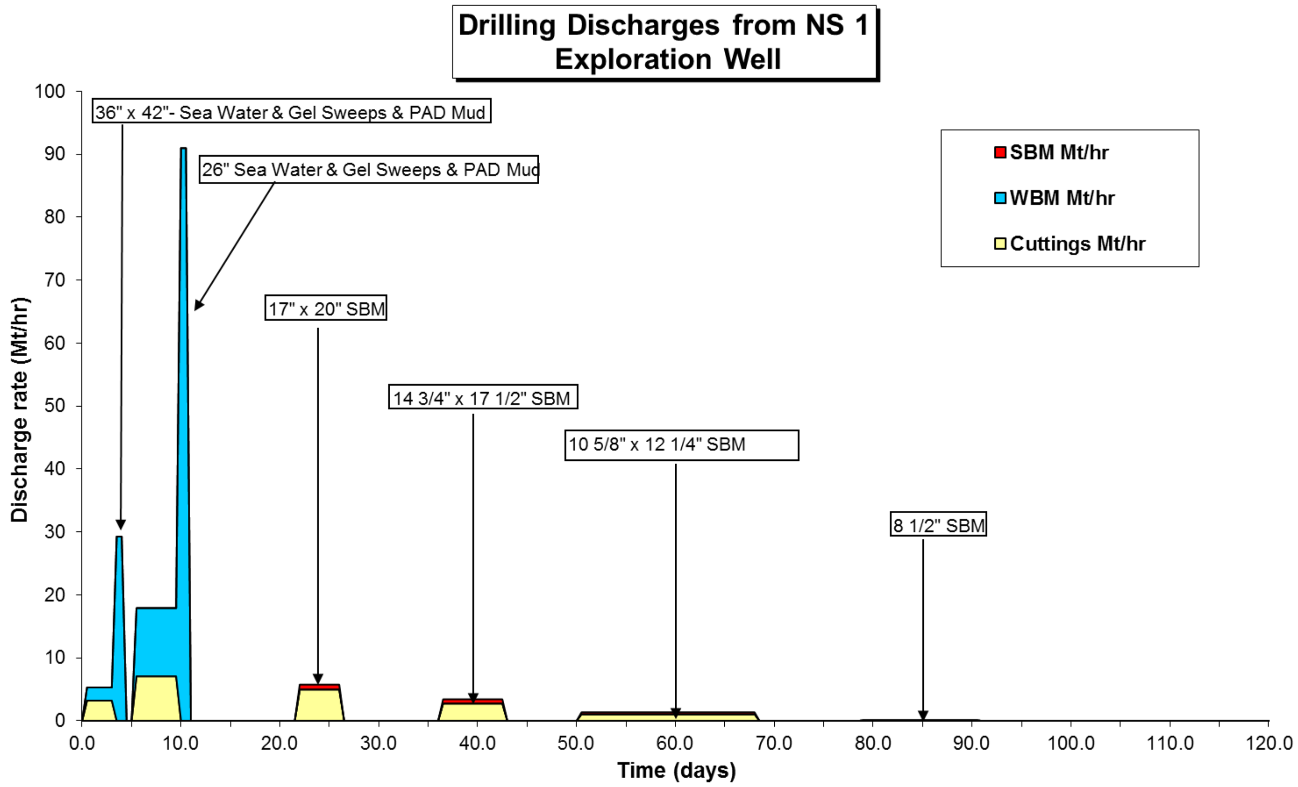
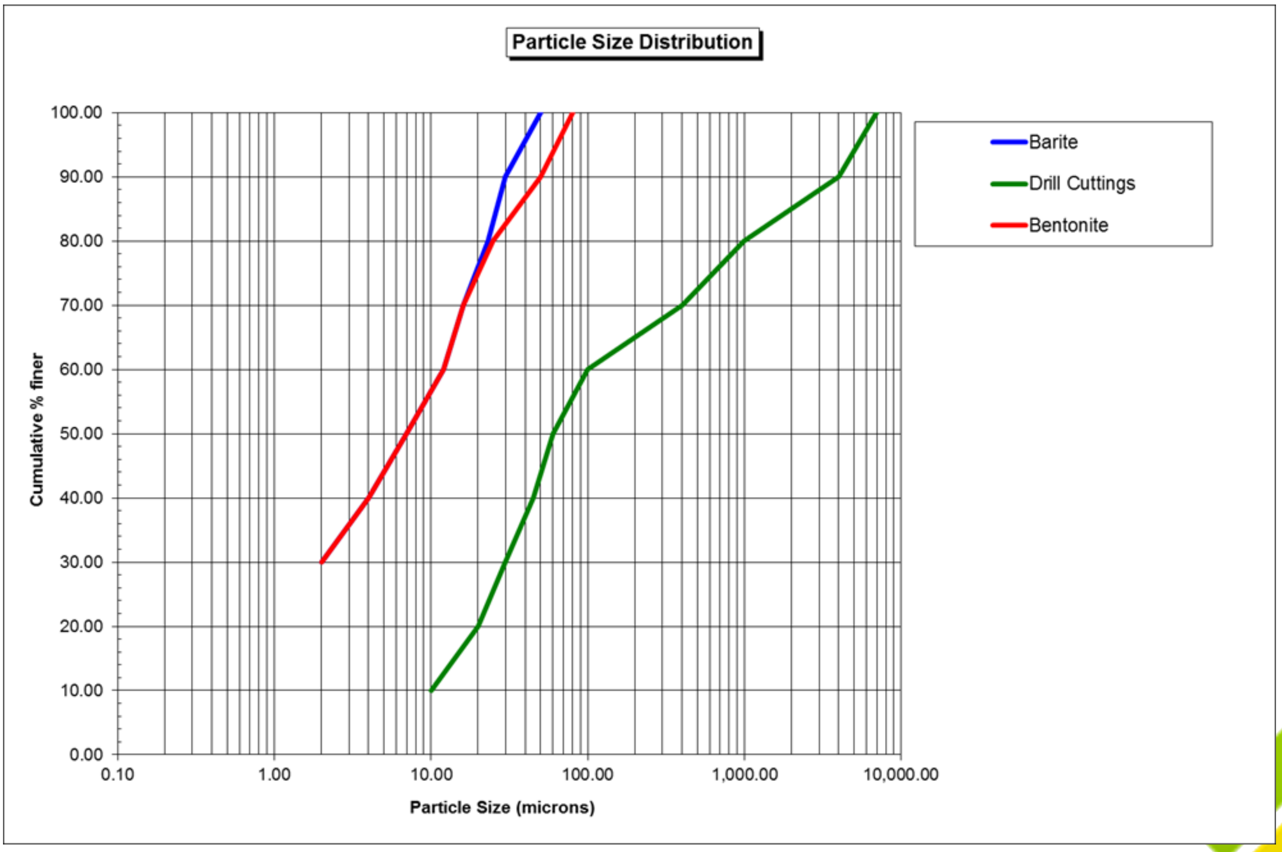


Figure 4.3 Size distributions of particulates used in GAB drilling discharge modelling



4.2 Environmental Data

4.2.1 Hydrodynamic and Wind Data

The regional current processes offshore Nova Scotia are dominated by the cold Labrador current that flows from the north along the continental shelf-break, and the warm North Atlantic current that flows towards the northeast and is located further offshore. The Labrador Current is shown in Figure 4.4, which indicates that its principle source is the West Greenland Current; however, flows through the Davis and Hudson straits are also important. The Figure also shows that the Labrador Current splits into two branches: an inshore and an offshore flow. The North Atlantic Current (Gulf Stream) is shown in Figure 4.5 which also shows the circulation across the shelves offshore Nova Scotia.

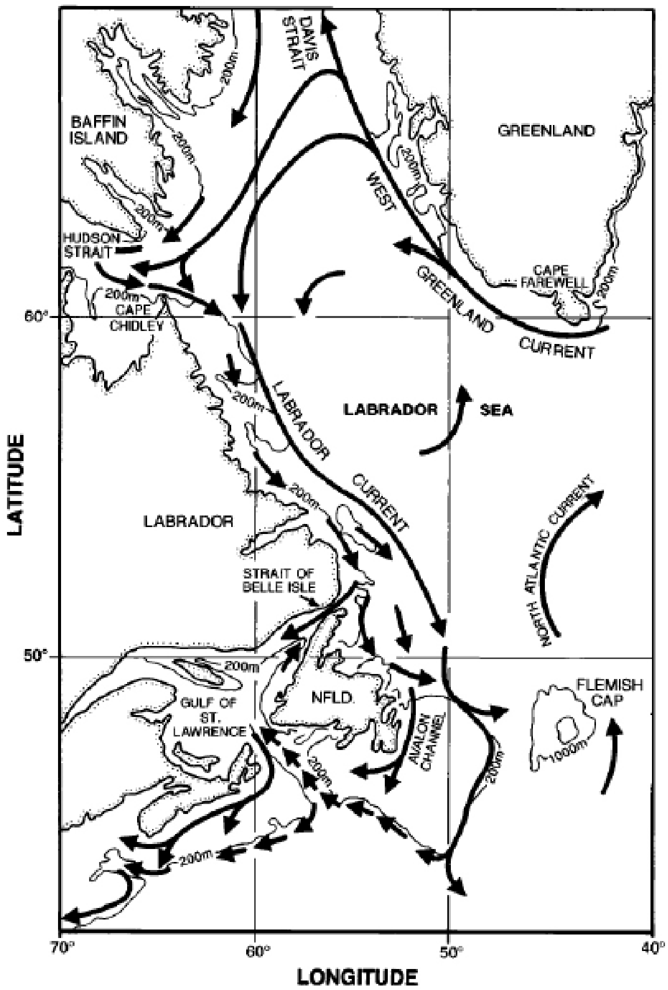


Figure 4.4 General circulation in the NorthWest Atlantic showing major current systems (from Colbourne et al.[10] and adapted from Chapman and Beardsley [11].

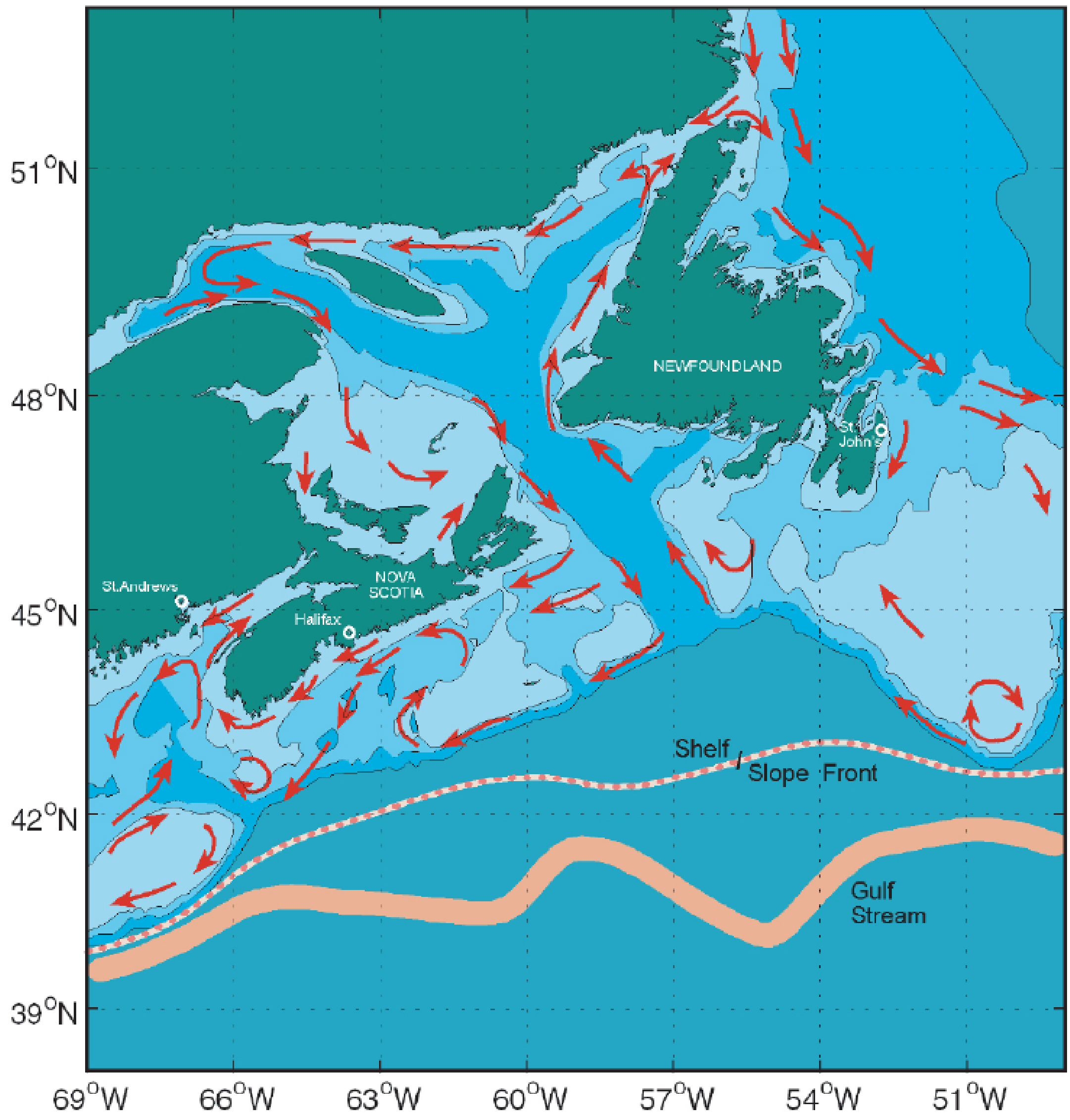


Figure 4.5 Schematic showing the surface circulation and the positions of the Shelf/Slope Front and the Gulf Stream (from Drinkwater and Gilbert [(12)]).

BP commissioned an independent, assurance review of potential metocean models to use in modelling work to support the Scotian Basin EIS. The review compared hindcast data of two potential metocean models to published data to identify which is the better representation of the expected conditions in the Scotian Basin[(13)].

The assurance work was designed to take account of the following features:

- **Regional:** circulation, sea surface height, sea surface temperature
- **Sub-regional:** circulation, temperature and salinity transects, tides, drifters
- **Scotian Shelf:** hydrography, moorings

The independent assurance assessment has demonstrated that the metocean model parameters listed in Table 4.5 provide the most accurate representation of the anticipated conditions in offshore Nova Scotia.

Hence, the 3-D current dataset used in DREAM modelling to drive drill cutting dispersion and pollutant transport was comprised of daily HYCOM current speeds with Bedford Institute Tides linearly superimposed. The HYCOM currents are from the Navy Research Laboratory experiment 91.1 (HYCOM GLBu0.08) and were interpolated onto a three hourly time step for the period 1st January 2006 and 31st December. The spatial resolution is 1/12.5 degrees and the results were extracted onto a domain that spans: longitude 45 to 75 degrees West and latitude 35 to 55 degrees North. The HYCOM currents were provided on forty depth levels, from the surface to 5,000 m. HYCOM uses Gebco 30 minute bathymetry, CFSR atmospheric forcing and assimilates data from a variety of sources. The tidal currents have been derived from the constituents in the BIO WebTide module (from the Scotian Shelf, North West Atlantic and Global grids) and the profile through depth was reconstructed by assuming a 1/7 power law.

Snapshot maps showing examples of the wind and current fields generated from the National Centre for Atmospheric Research (NCAR) / National Centre for Environmental Protection (NCEP) Climate Forecast System Reanalysis (CFSR) and HYCOM datasets respectively are presented in Figures 4.6 – 4.8. The HYCOM model was also used to extract average monthly temperature and salinity vs. depth profiles over the release locations for use in the dispersion modelling.

Table 4.5 Metocean Data Parameter Inputs

	Input Data	Reference
Bathymetry	GEBCO-1 minute	http://www.gebco.net/
Current velocity components	HYCOM	https://hycom.org/
Sea-surface elevation	HYCOM	https://hycom.org/
Temperature	HYCOM	https://hycom.org/
Salinity	HYCOM	https://hycom.org/
Tides	Bedford Institute Tides	http://www.tide-forecast.com/locations/Bedford-Institute-Nova-Scotia/tides/latest
Winds	NCAR /NCEP (CFSR)	http://rda.ucar.edu/pub/cfsr.html
Atmospheric forcing	NCAR/NCEP (CFSR)	http://rda.ucar.edu/pub/cfsr.html
Wave heights	Calculated in OSCAR	n/a
Wind induced current	Calculated in OSCAR	n/a

Figure 4.6 Snapshot map showing an example of the 2-dimensional wind field generated from the NCAR / NCEP (CFSR) dataset

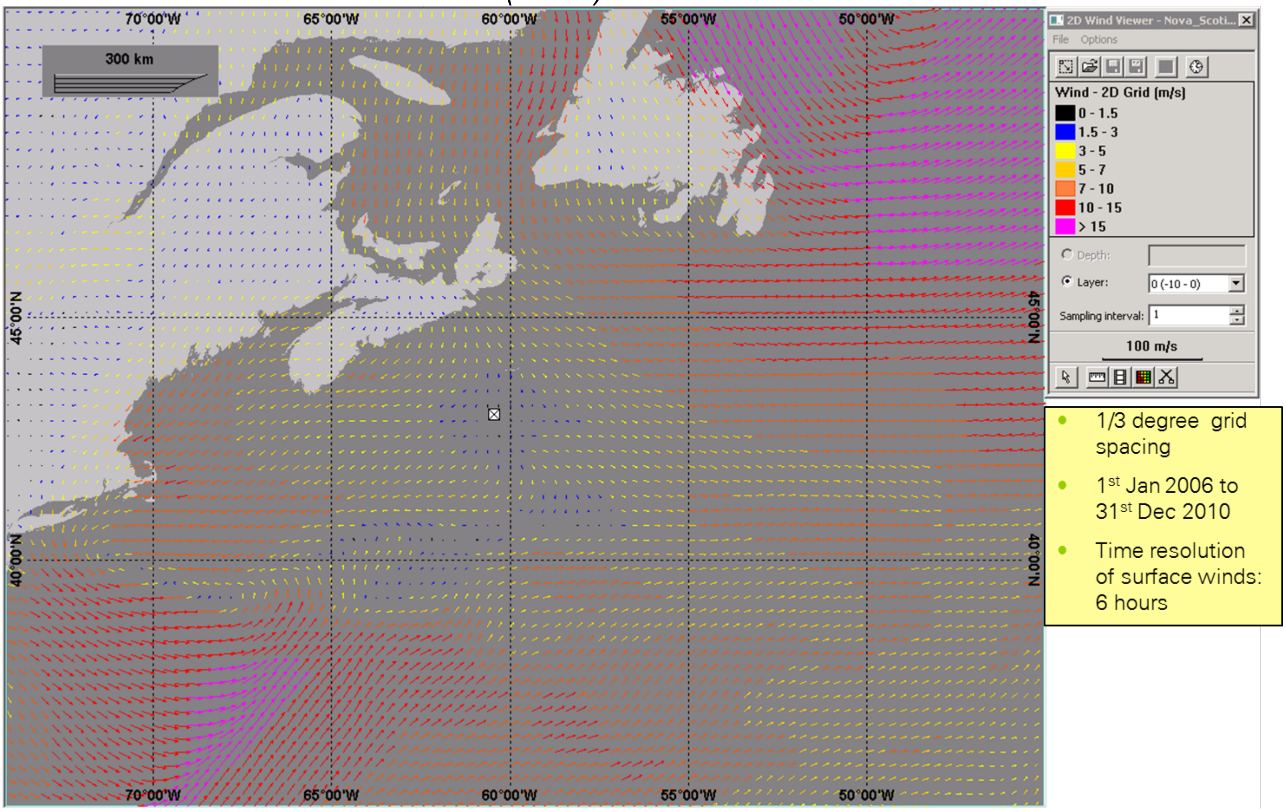


Figure 4.7 Snapshot map showing an example of the surface current field from 3-dimensional HYCOM generated dataset

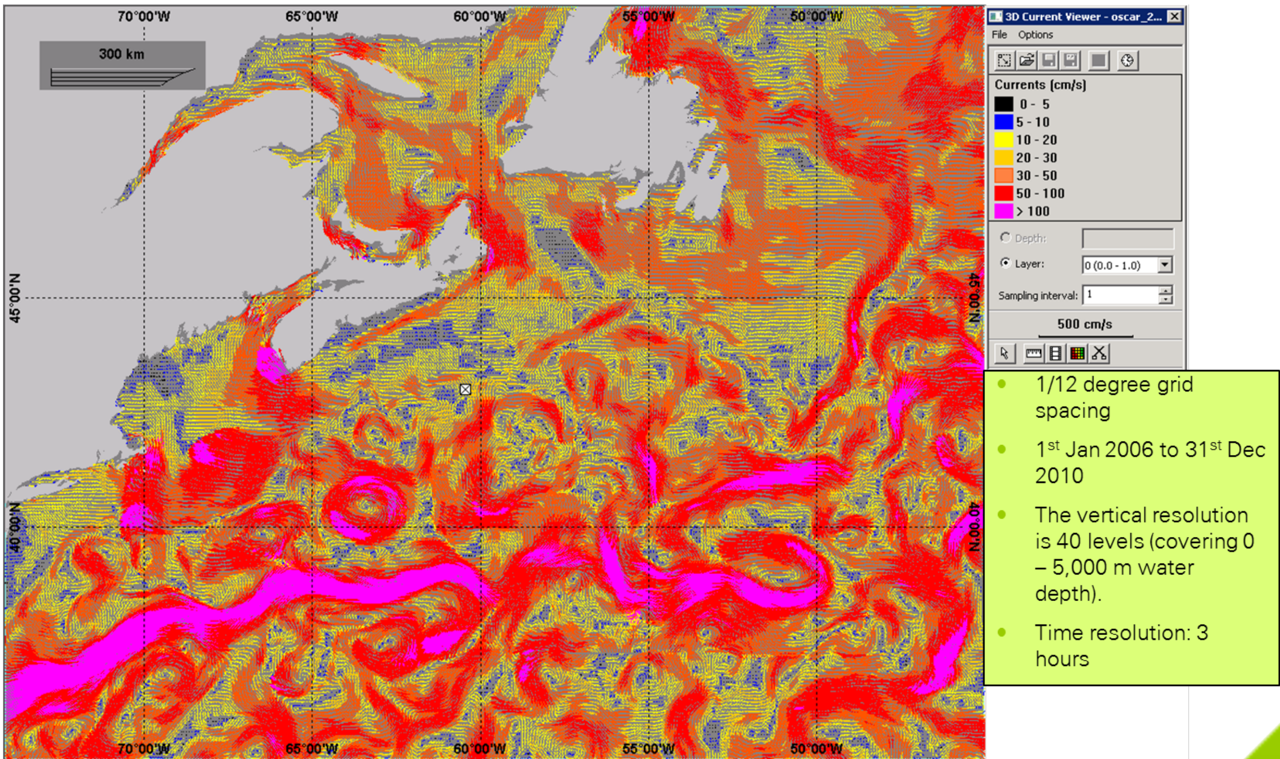
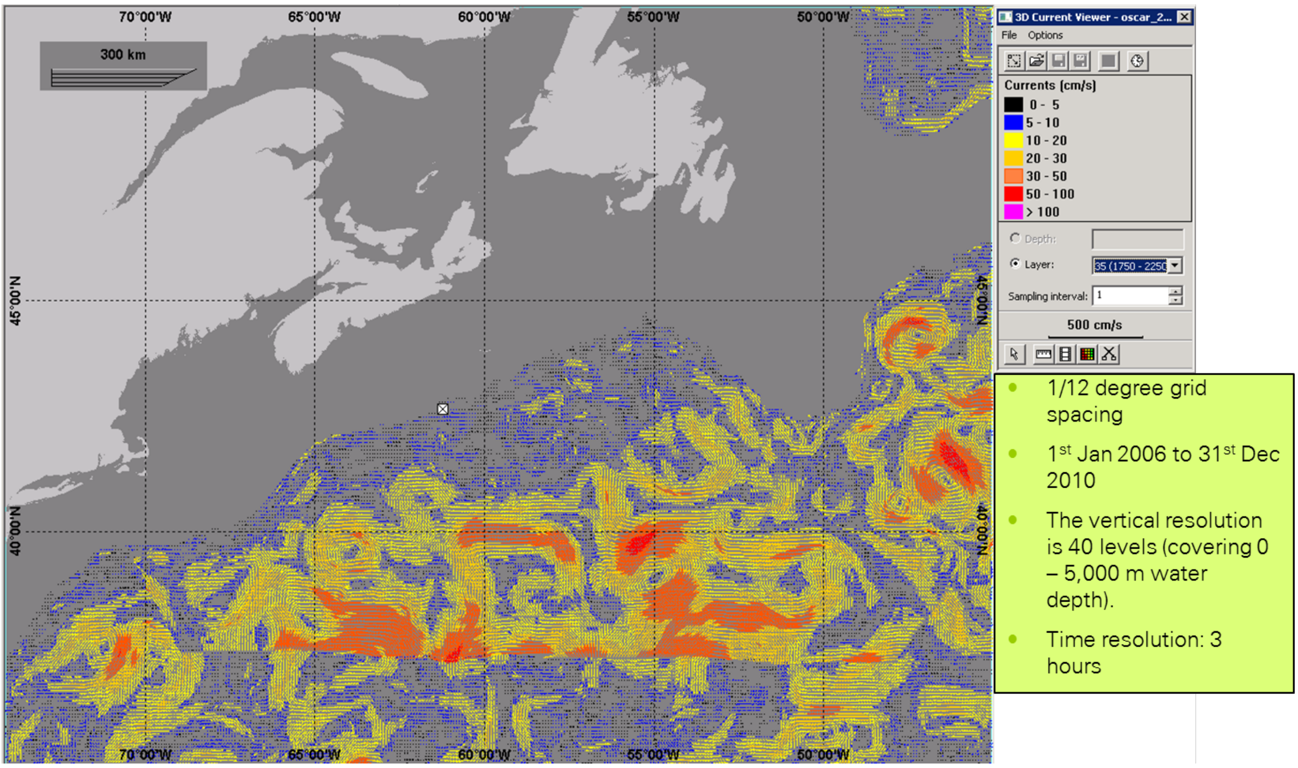


Figure 4.8 Snapshot map showing an example of the current field for the water depth range 1,750 - 2,250 m extracted from the 3-dimensional HYCOM generated dataset



4.2.2 Habitat and Depths

The MEMW system refers to several internal depth data sources for building depth grids. (Sea Topo 8.0, IBCAO, beta version).

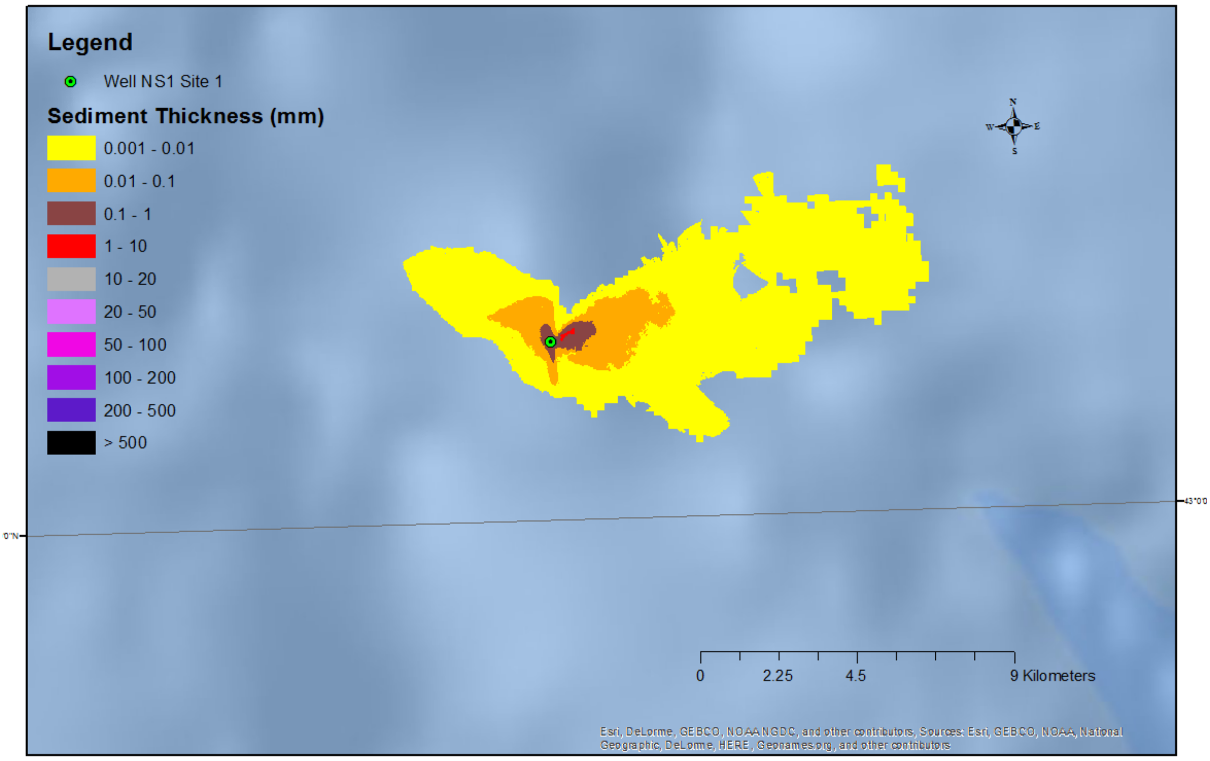
5 Results and discussion

5.1 Site 1 – Shallowest water depth scenario

Figures 4.9 shows the predicted post-drilling seabed deposition footprint of drilling discharge particulate matter for the “shallow water depth well location scenario and a summer (1st July) spud date. The predicted deposition footprint is predominantly towards the East and North East for the surface discharges (see Figure 4.13).

Figure 4.9 Seabed deposition footprint of drilling discharges at Site 1 (shallowest water depth well location). Spud date 1st July 2010.

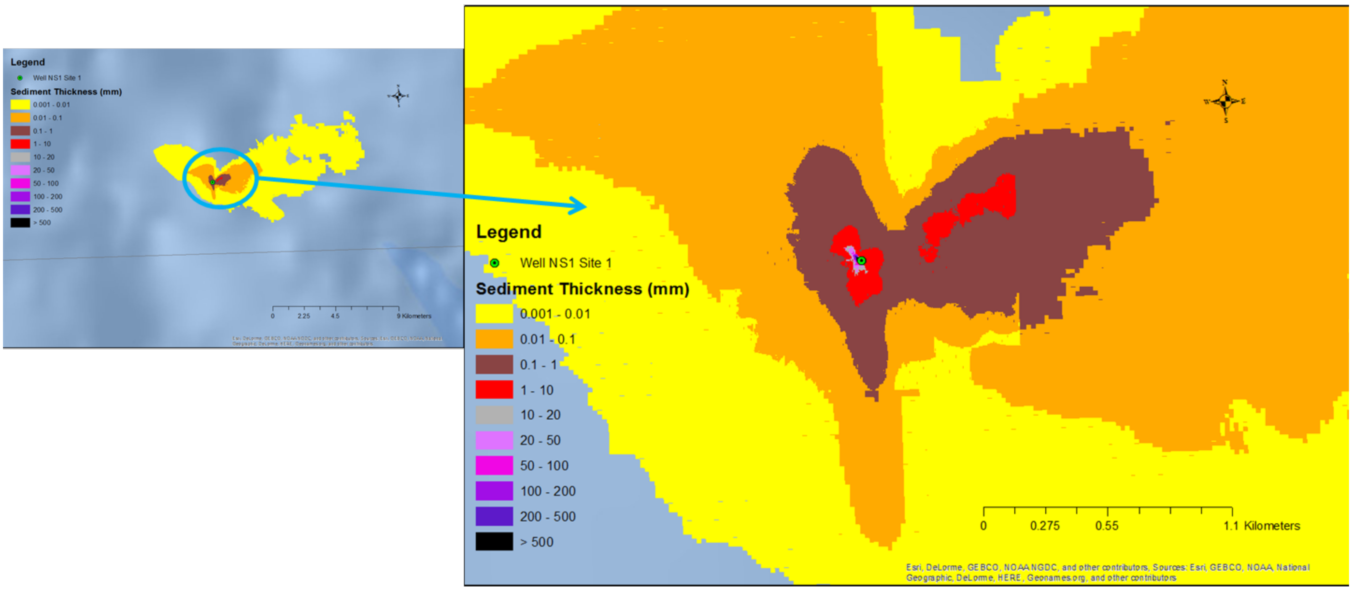
Well NS-1 Drill Solids Sediment Deposition Map - Site 1



Although >50% by weight of the mud and cuttings released was transported outside the boundaries of the modelling domain (115 km x 110 km), the quantity of material involved is extremely small compared with the water volume in which the material is dispersing. Thus, the resulting effect on oceanic suspended particulate matter concentrations is likely to be indistinguishable. Moreover, Figure 4.9 shows that although some particles were deposited outside of the modelling domain, these were at insignificant thicknesses of less than 0.001mm (1 micron). The deposition area within the yellow area represents a deposition thickness of >1 micron, which in reality defines the boundary of the area within which particulate material associated with the drilling discharges might be detected through sediment chemical analysis to identify elevated levels of barium and other metals. The area measures 15 km x 10 km across in the E-W x NW-SE directions at its maximum extent and covers circa 4,870 hectares

The predicted near-field deposition area is shown in Figure 4.10. The deposition thickness is >1 mm within the "red" area which defines the area where any drilling discharge solids deposited on the seafloor might be visible. It consists of two areas measuring approximately 563 m x 325 m across the SW-NE and NW-SE axes respectively with a combined area of circa 10 hectares.

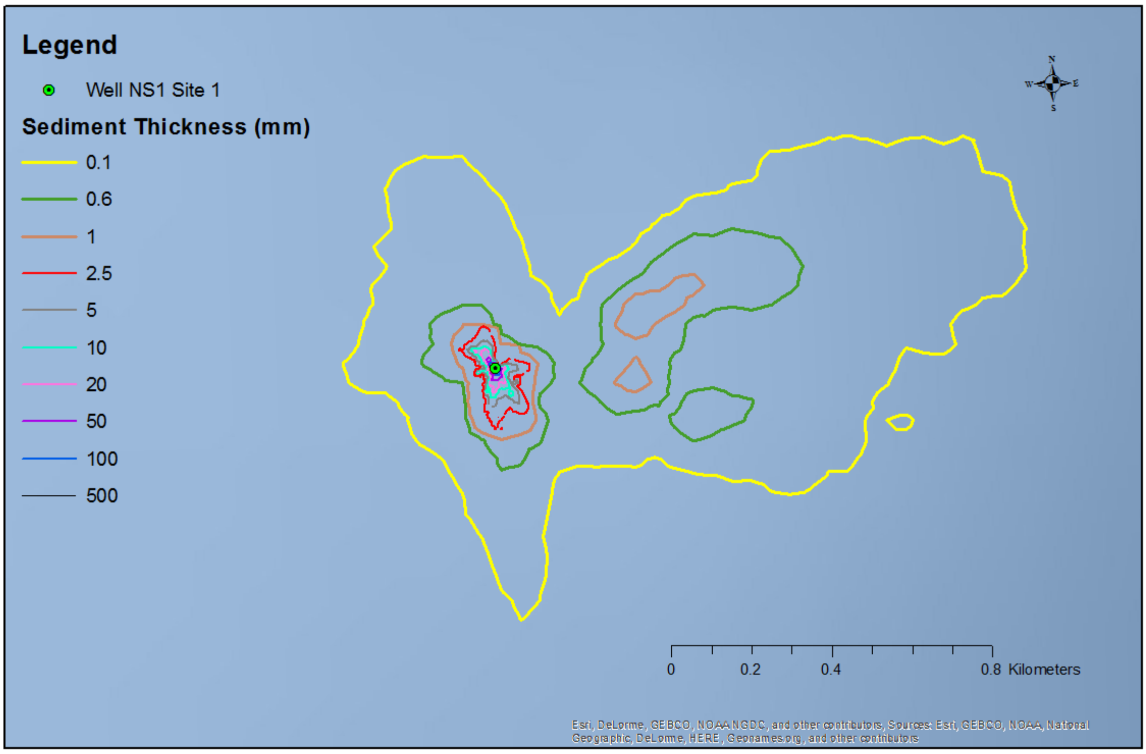
Figure 4.10 Seabed deposition footprint of drilling discharges at Site 1 (shallowest water depth well location). Spud date 1st July 2010. (Right) Expanded scale (higher grid cell spatial resolution of 20 m x 20 m)



More detailed contour plots showing the predicted deposition thickness of drilling discharges at contours above 0.1 mm are presented in Figure 4.11

Figure 4.11 Predicted thickness of drilling discharges at Site 1 (shallowest water depth well location). Spud date 1st July 2010. Top: Thickness shown as contours above 0.1 mm. Bottom: Expanded scale zoomed in over the release site

Well NS-1 Drill Solids Sediment Deposition Map - Site 1



Well NS-1 Drill Solids Sediment Deposition Map - Site 1

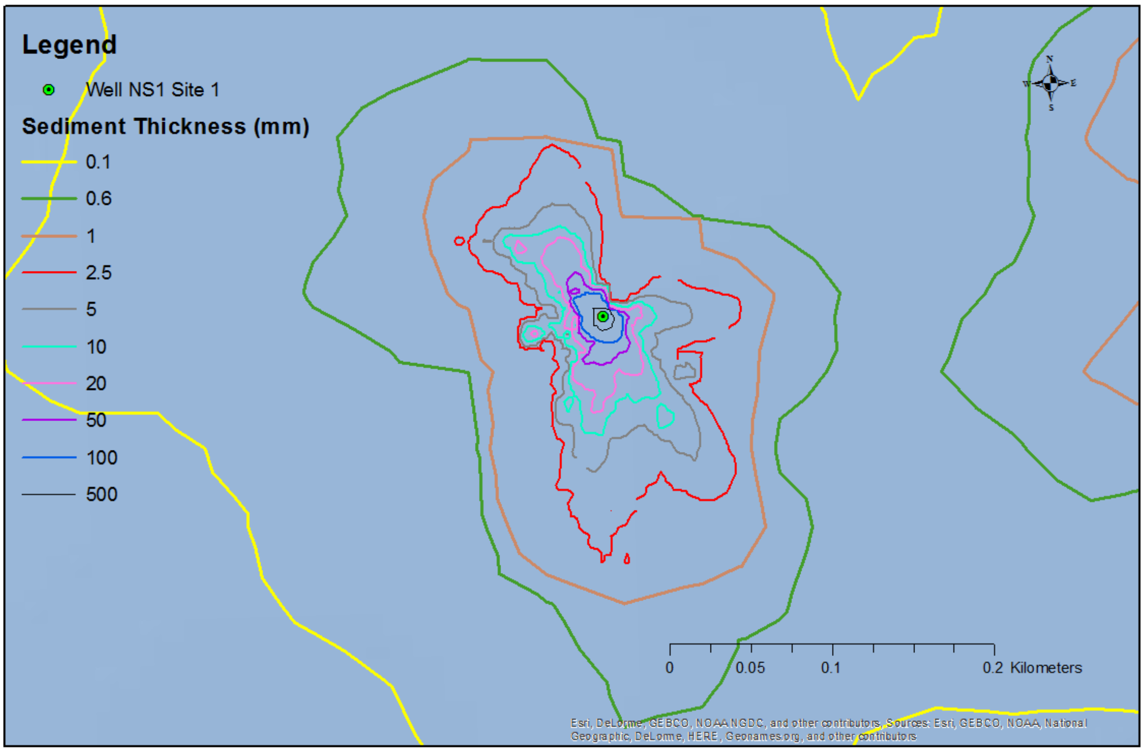


Table 6.1 summarizes the predicted distances (maximum extent) from the discharge point for various deposition thicknesses associated with sedimentation from drilling discharges for Site 1 and Table 6.2 summarizes the predicted areal coverage of sedimentation.

This data can be used to predict potential environmental effects on the benthic environment. At deposition thicknesses of approximately 10 mm or more, benthic communities comprised of sedentary or slow moving species, may be smothered and the sediment quality will be altered in terms of nutrient enrichment and oxygen depletion. Using an average burial depth of 9.6 mm as a minimum threshold where we would expect to see adverse effects to benthic organisms (Neff et al. 2004 [(14)]), then the modelling results predict that these sediment thicknesses could extend approximately 78 m from the discharge point, or cover an area of approximately 0.54 hectares per well. Thicknesses of 100 mm or greater are confined of distance of 20 m from the discharge site and an aerial extent of 0.066 hectares (660 m^2).

Table 6.1 Predicted Maximum Extent of Deposition from the Discharge Point at Site 1

Deposition thickness (mm)	Site 1 Well Location
	Maximum Extent from Discharge Point (m)
0.001	11,213
0.01	3,684
0.1	1,367
1	563
2.5	150
5	102
10	78
20	71
50	33
100	21
500	7

Table 6.2 Predicted Areal Extent of Sedimentation from Drilling Discharges at Site 1

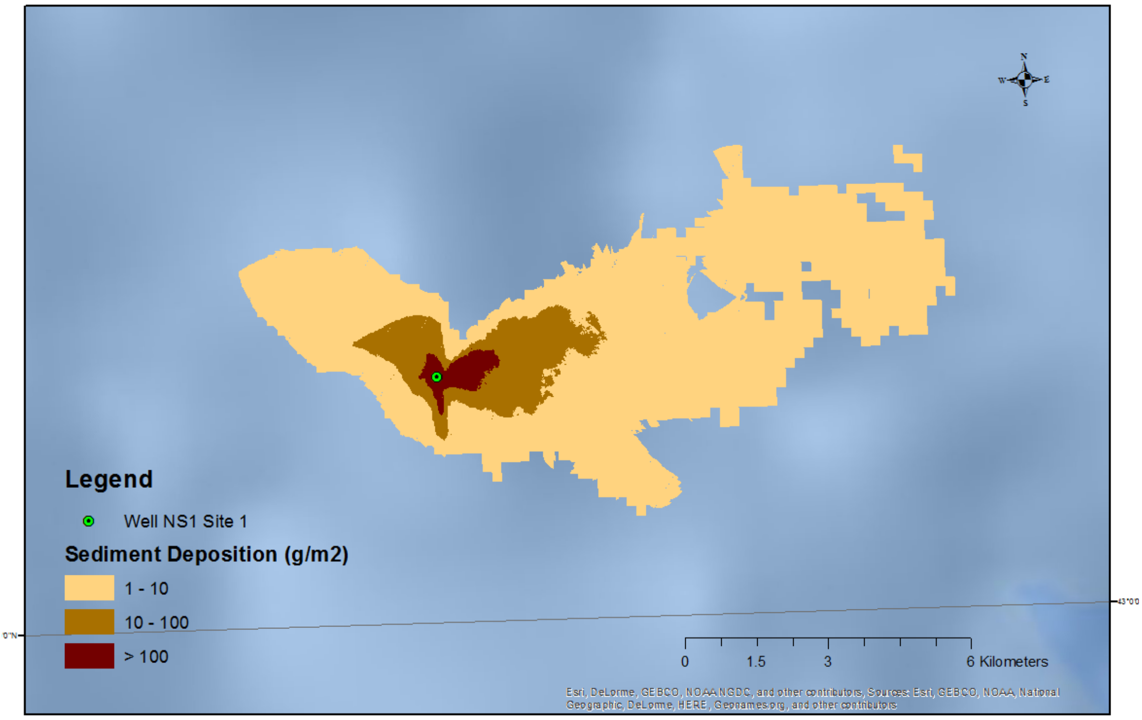
Deposition thickness (mm)	Site 1 Well Location - Cumulative Area Exceeding		
	Hectares	Sq km	m^2
0.001	4,872.7305	48.72731	48,727,305
0.01	703.7430	7.03743	7,037,430
0.1	104.7752	1.04775	1,047,752
0.2	58.2847	0.58285	582,847
0.5	28.1940	0.28194	281,940
1	9.9089	0.09909	99,089
2	2.5045	0.02504	25,045
5	0.9891	0.00989	9,891
10	0.5388	0.00539	5,388
20	0.2960	0.00296	2,960
50	0.1164	0.00116	1,164
100	0.0658	0.00066	658
200	0.0354	0.00035	354
500	0.0177	0.00018	177

A map showing the concentration of deposited material on the seabed is presented in Figure 4.12. The area where sediment concentrations exceed a threshold of >10 g/m2 measure 4.9 km x 2.6 km across in the E-W x N-S directions at its maximum extent and covers 670 hectares.

Figure 4.13 shows the contribution to sediment footprint and thickness for each of the solid components released in the drilling discharges (drill cuttings from each hole section, bentonite and barite). As expected, the predicted deposition footprint of discharges from the two 'top hole' riserless sections discharged directly onto the seabed is localised around the wellhead location, whereas material from subsequent hole sections discharged at the sea surface were spread over a much larger area.

Figure 4.12 Map showing the predicted concentration of drilling discharge particulate material deposited on the seabed at Site 1 (shallowest water depth well location). Spud date 1st July 2010. Bottom: Expanded scale zoomed in over the release site, concentrations shown as contours above 1 g/m²

Well NS-1 Drill Solids Sediment Deposition Map - Site 1



Well NS-1 Drill Solids Sediment Deposition Map - Site 1

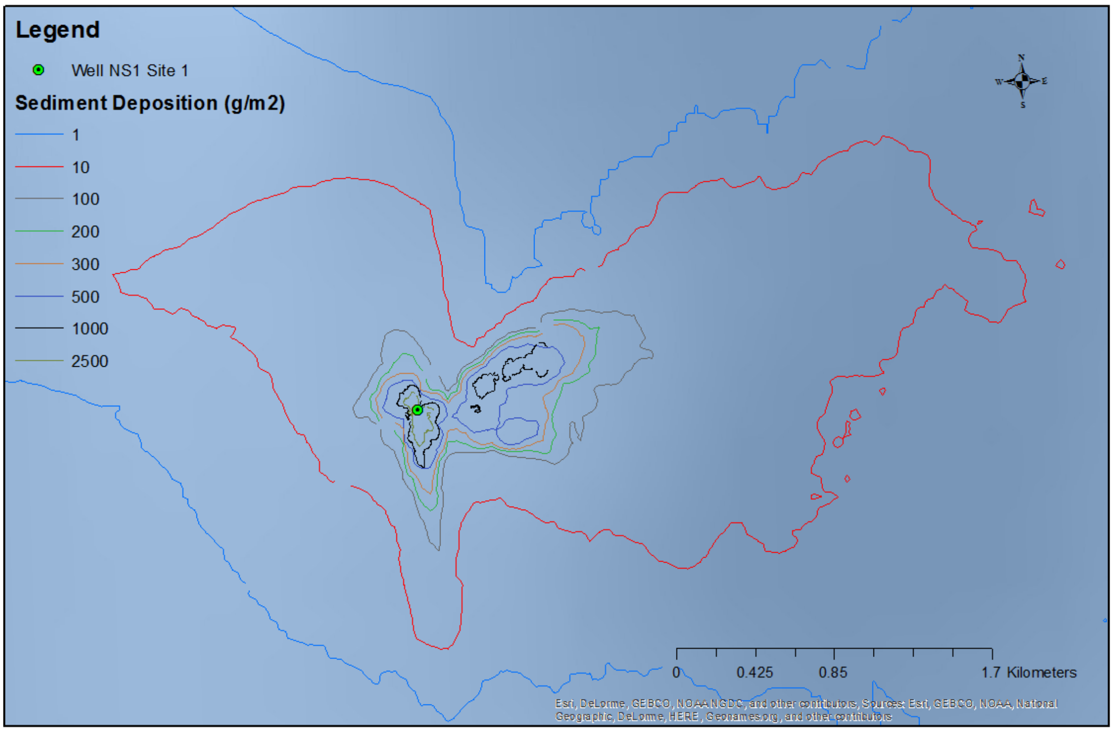
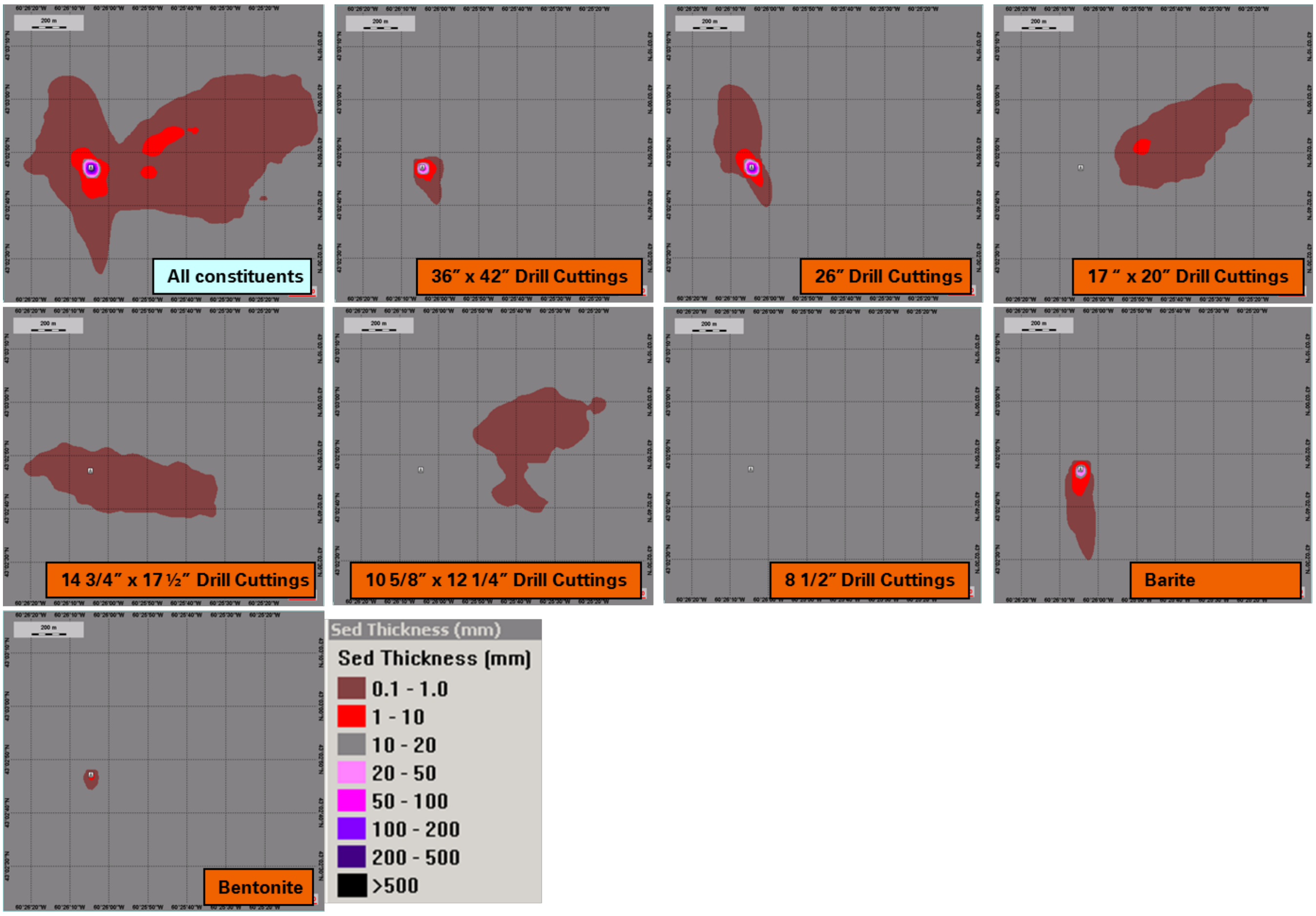


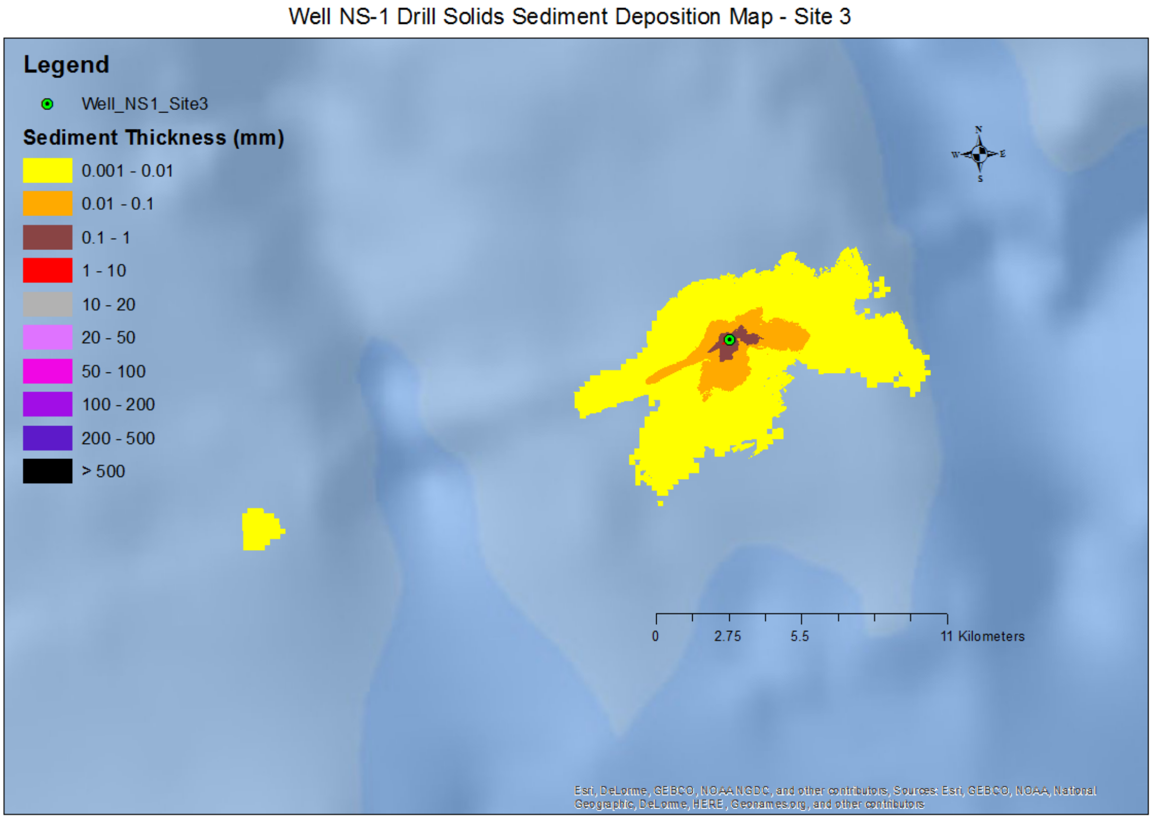
Figure 4.13 Contribution to seabed deposition footprint and thickness from solid components (drill cuttings, bentonite and barite) released in the drilling discharges at Site 1 (shallowest water depth well location). Spud date 1st July 2010.



5.2 Site 3 – Deepest water depth scenario

Figures 4.14 shows the predicted post-drilling seabed deposition footprint of drilling discharge particulate matter for the deepest water depth well location scenario and a summer (1st July) spud date.

Figure 4.14 Seabed deposition footprint of drilling discharges at Site 3 (deepest water depth well location). Spud date 1st July 2010.



46% by weight of the mud and cuttings released was transported outside the boundaries of the modelling domain (102 km x 95 km). The predicted deposition footprint is predominantly towards the South West and extends over a greater area (by 10 – 15%) than for the shallow water depth well location (Site 1) for thickness thresholds < 0.5 mm, as the increased water depth means that finer drill solids released in the surface discharges are transported over a greater distance before settling (See Table 6.3 and 6.4)

The maximum extent of the yellow boundary deposition area (> 1 microns deposit thickness) measures circa 20.3 km from the discharge point at Site 3 and covers 5,350 hectares (compared to 4,870 hectares at Site 1).

The near-field red boundary deposition area at Site 3 (see Figure 4.15), where the predicted thickness of deposited drill solids is > 1 mm thickness (“visible” threshold), extends circa 360 m from the discharge point in a South Westerly direction at its maximum extent and covers 4.2 hectares, which is less than half the area coverage at Site 1.

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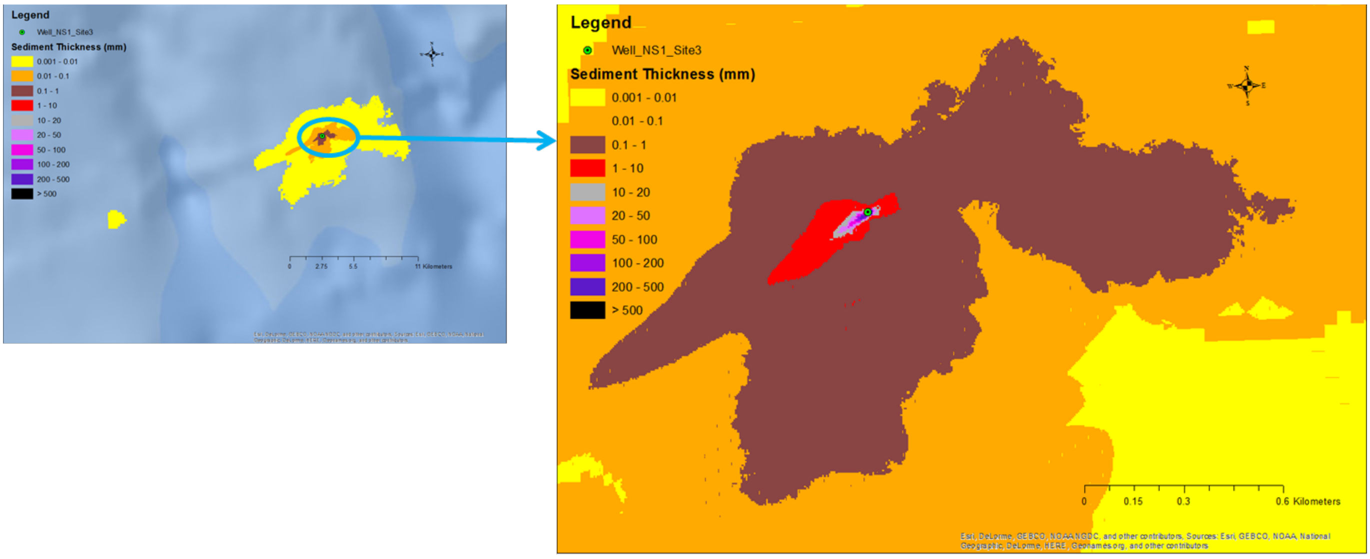
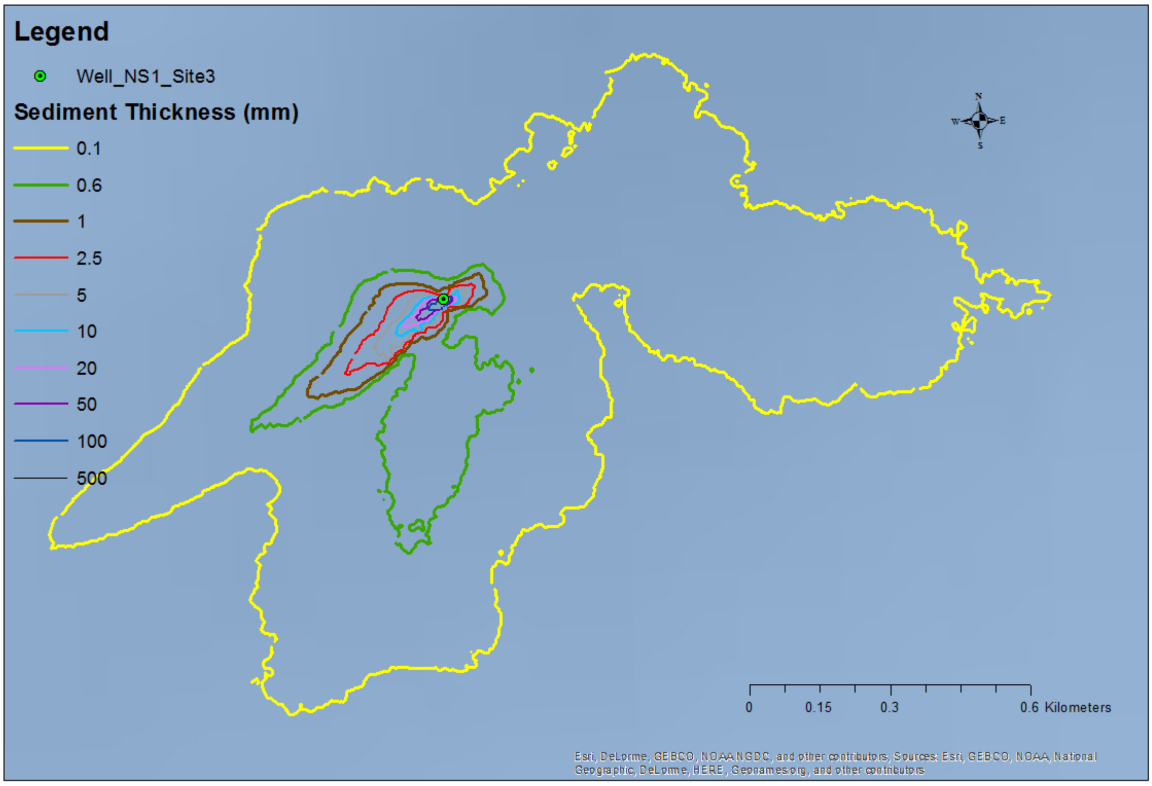
Figure 4.15 Seabed deposition footprint of drilling discharges at Site 3 (deepest water depth well location). Spud date 1st July 2010. (Right) Expanded scale (higher grid cell spatial resolution of 20 m x 20 m)



More detailed contour plots showing the predicted deposition thickness of drilling discharges at contours above 0.1 mm are presented in Figure 4.16

Figure 4.16 Predicted thickness of drilling discharges at Site 3 (deepest water depth well location). Spud date 1st July 2010. Top: Thickness shown as contours above 0.1 mm. Bottom: Expanded scale zoomed in over the release site.

Well NS-1 Drill Solids Sediment Deposition Map - Site 3



Well NS-1 Drill Solids Sediment Deposition Map - Site 3

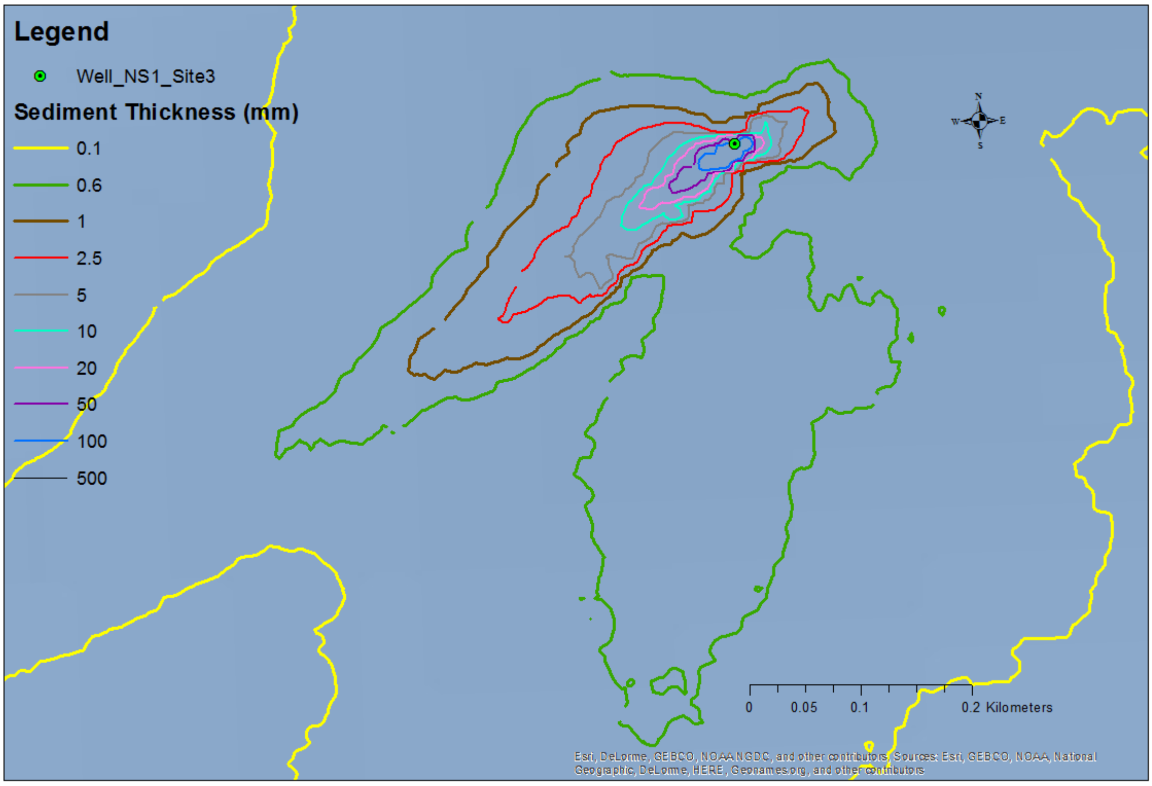


Table 6.3 summarizes the predicted distances (maximum extent) from the discharge point for various deposition thicknesses associated with sedimentation from drilling discharges for Site 3 and Table 6.4 summarizes the predicted areal coverage of sedimentation.

Using an average burial depth of 9.6 mm as a minimum threshold where we would expect to see adverse effects to benthic organisms (Neff et al. 2004 [(14)]), then the modelling results predict that these sediment thicknesses could extend approximately 116 m from the discharge point, or cover an area of approximately 0.54 hectares per well. Thicknesses of 100 mm or greater are confined of distance of 30 m from the discharge site and an aerial extent of 0.066 hectares (685 m2).

Table 6.3 Predicted Maximum Extent of Deposition from the Discharge Point at Site 3

Deposition thickness (mm)	Site 3 Well Location
	Maximum Extent from Discharge Point (m)
0.001	20,130
0.01	3,547
0.1	1,309
1	358
2.5	251
5	167
10	116
20	93
50	62
100	30
500	15

Table 6.4 Predicted Areal Extent of Sedimentation from Drilling Discharges at Site 3

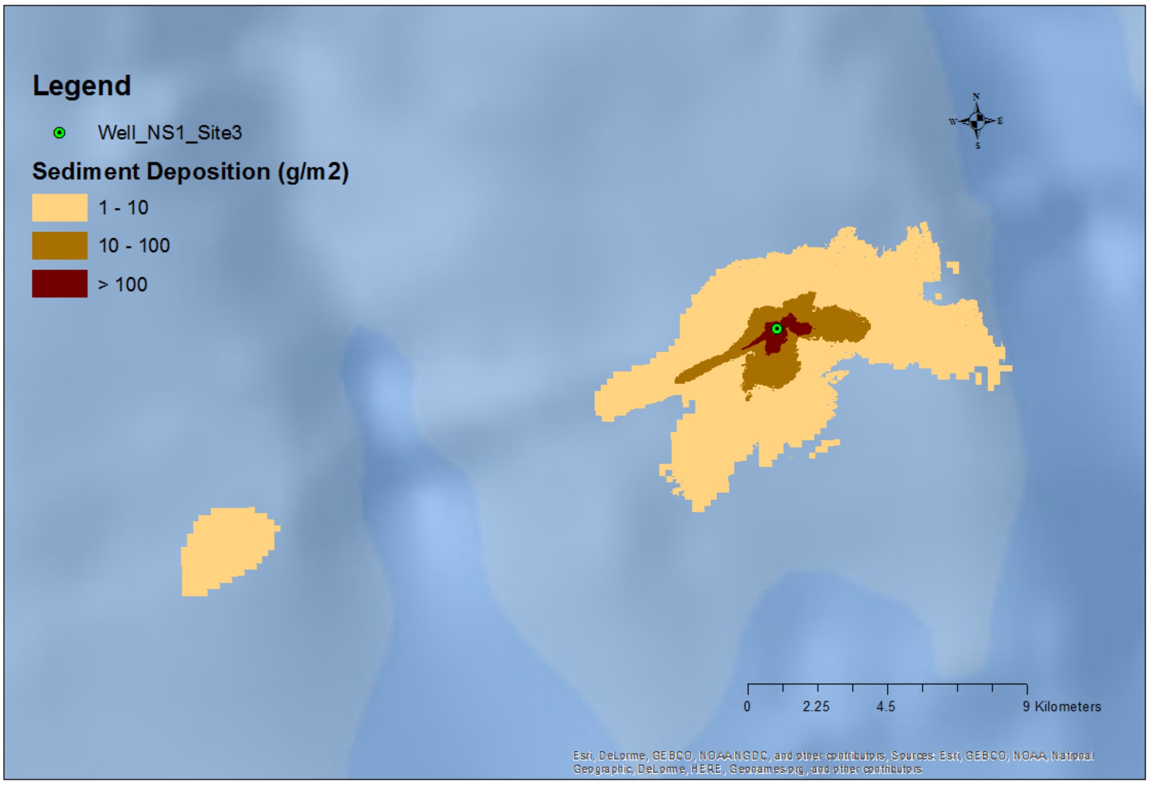
Deposition thickness (mm)	Site 3 Well Location - Cumulative Area Exceeding		
	Hectares	Sq km	m^2
0.001	5,352.8105	53.52811	53,528,105
0.01	796.2614	7.96261	7,962,614
0.1	116.2959	1.16296	1,162,959
0.2	66.8110	0.66811	668,110
0.5	18.7219	0.18722	187,219
1	4.1702	0.04170	41,702
2	2.3199	0.02320	23,199
5	1.0889	0.01089	10,889
10	0.5356	0.00536	5,356
20	0.2970	0.00297	2,970
50	0.1320	0.00132	1,320
100	0.0685	0.00069	685
200	0.0381	0.00038	381
500	0.0102	0.00010	102

A map showing the concentration of deposited material on the seabed is presented in Figure 4.17. The area where sediment concentrations exceed a threshold of >10 g/m2 covers 790 hectares (compared to 670 hectares at Site 1).

Figure 4.18 shows the contribution to sediment footprint and thickness for each of the solid components released in the drilling discharges (drill cuttings from each hole section, bentonite and barite).

Figure 4.17 Map showing the predicted concentration of drilling discharge particulate material deposited on the seabed at Site 3 (deepest water depth well location). Spud date 1st July 2010. Bottom: Expanded scale zoomed in over the release site, concentrations shown as contours above 1 g/m²

Well NS-1 Drill Solids Sediment Deposition Map - Site 3



Well NS-1 Drill Solids Sediment Deposition Map - Site 3

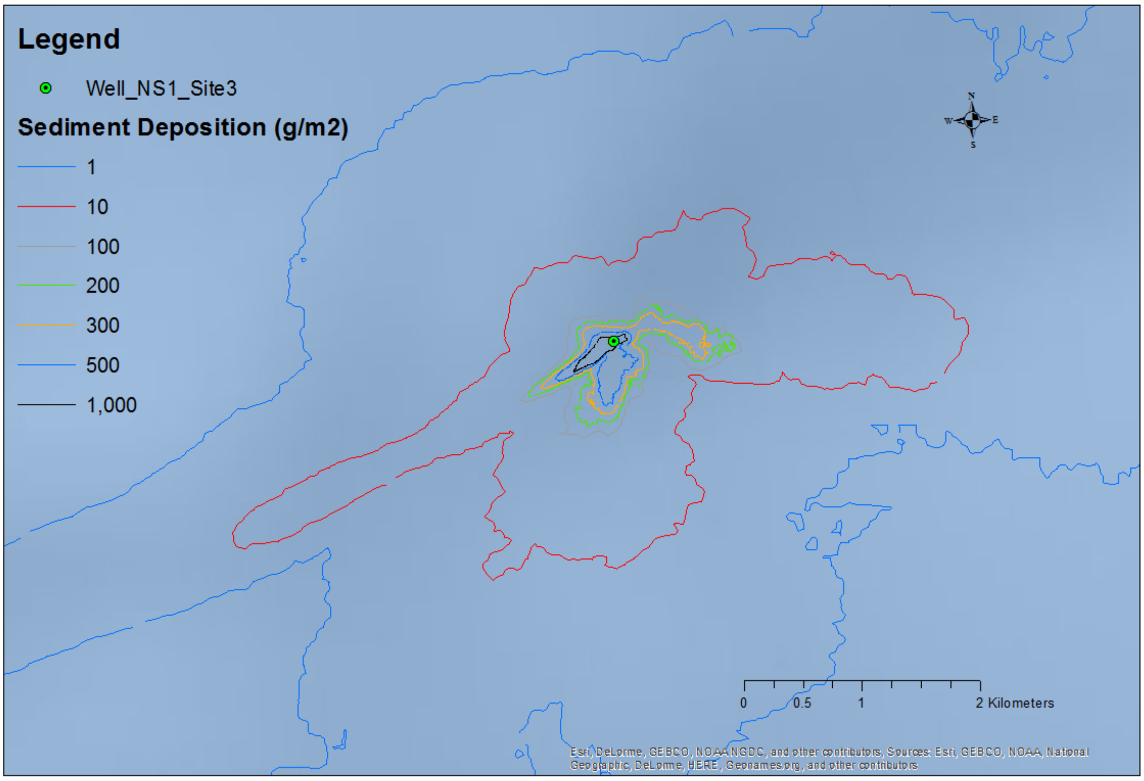
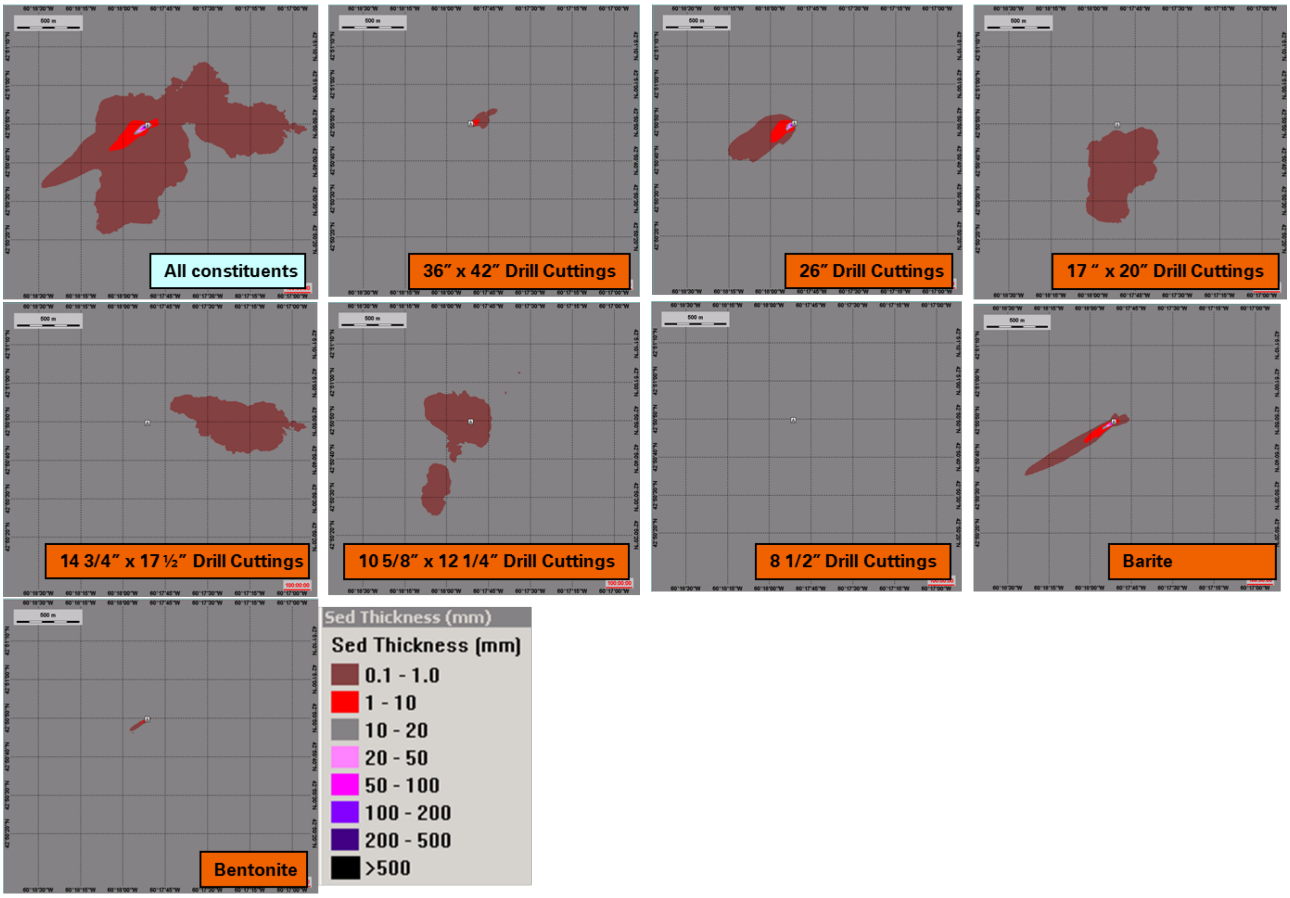


Figure 4.18 Contribution to seabed deposition footprint and thickness from solid components (drill cuttings, bentonite and barite) released in the drilling discharges at Site 1 (shallowest water depth well location). Spud date 1st July 2010.



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Appendix 1 Breakdown of drilling discharge composition by hole section for the NS-1 exploration well

Table A1 - Section 1

SECTION 1				
Drilling Fluid Formulation 36" x 42" Hole				
Bit Diameter (ins)	42.00	**Section Length (m)**		100
Wellbore Washout (Volume %)	25%	**Drilling Rate (m/hr)**		1.44
Mud Density	**SG**	**[ppg]**	**Start of Discharge (time since previous discharge stopped, days)**	0.00
Hi Vis Sweep	1.05	8.76		
PAD Displacement Mud	1.26	10.50		
Mud Type (WBM/OBM/SBM)	WBM			
Mud Description	Guar Gum HiVis Sweeps / PAD Displacement Mud (Riserless Drilling)			
Discharge temperature at release point (deg C)	18 deg C			
Discharge Depth (m)	**Above sea-floor**		**Below sea surface**	
	1		-	
Diameter of outlet opening (m)	-			
Orientation of outlet opening	Vertical, up			
Weight of Cuttings Discharged (MT)	223.86			
Hi Vis Sweep				
Volume of Mud Discharged (m^3)	139.10			
Weight of Mud Discharged (MT)	146.05			
PAD Displacement Mud				
Volume of Mud Discharged (m^3)	559.00			
Weight of Mud Discharged (MT)	703.23			
Composition	**[kg/m3]**	**[ppb]**	**MT**	**Comments**
Guar Gum Sweeps				
Polysaccharide (Viscosifier)	17.12	6.0	2.381	PLONOR
PAD Displacement Mud				
Bentonite (Viscosifier)	7.51	2.6	4.197	PLONOR
Barite (Weighting Agent)	330.95	116.0	185.002	PLONOR
Caustic Soda (pH control)	0.75	0.3	0.420	
Soda Ash (pH control)	0.75	0.3	0.420	
Non-fermenting starch (Filtration control)	2.25	0.8	1.259	
Polyanionic cellulose (Fluid Loss Control	2.25	0.8	1.259	
Xanthan Gum (Viscosifier)	0.75	0.3	0.420	
Sub Total			**192.976**	
Total Chemicals Discharged			**195.357**	

Table A2 - Section 2

SECTION 2				
Drilling Fluid Formulation 26" Hole				
Bit Diameter (ins)	26.00	**Section Length (m)**		800
Wellbore Washout (Volume %)	33%	**Drilling Rate (m/hr)**		7.46
Mud Density	**SG**	**[ppg]**	**Start of Discharge (time since previous discharge stopped, days)**	1.20
Hi Vis Sweep	1.05	8.76		
PAD Displacement Mud	1.35	11.30		
Mud Type (WBM/OBM/SBM)	WBM			
Mud Description	Guar Gum HiVis Sweeps / PAD Displacement Mud (Riserless Drilling)			
Discharge temperature at release point (deg C)	18 deg C			
Discharge Depth (m)	**Above sea-floor**		**Below sea surface**	
	1		-	
Diameter of outlet opening (m)	-			
Orientation of outlet opening	Vertical, up			
Weight of Cuttings Discharged (MT)	766.12			
Hi Vis Sweep				
Volume of Mud Discharged (m^3)	1,112.76			
Weight of Mud Discharged (MT)	1,168.40			
PAD Displacement Mud				
Volume of Mud Discharged (m^3)	1,613.15			
Weight of Mud Discharged (MT)	2,184.20			
Composition	**[kg/m3]**	**[ppb]**	**MT**	**Comments**
Guar Gum Sweeps				
Polysaccharide (Viscosifier)	17.12	6.0	19.048	PLONOR
PAD Displacement Mud				
Bentonite (Viscosifier)	10.19	3.6	16.437	PLONOR
Barite (Weighting Agent)	459.33	161.0	740.975	PLONOR
Caustic Soda (pH control)	1.02	0.4	1.644	
Soda Ash (pH control)	1.02	0.4	1.644	
Non-fermenting starch (Filtration control)	3.06	1.1	4.931	
Polyanionic cellulose (Fluid Loss Control Agent)	3.06	1.1	4.931	
Xanthan Gum (Viscosifier)	1.02	0.4	1.644	
Sub Total			**772.205**	
Total Chemicals Discharged			**791.253**	

Table A3 - Section 3

SECTION 3				
Drilling Fluid Formulation 17" x 20" Hole				
Bit Diameter (ins)	20.00	**Section Length (m)**		950
Wellbore Washout (Volume %)	16%	**Drilling Rate (m/hr)**		9.59
Mud Density	**SG**	**[ppg]**	**Start of Discharge (time since previous discharge stopped, days)**	11.11
	1.27	10.60		
Mud Type (WBM/OBM/SBM)	SBM			
Mud Description	Assume Average 75/25 o/w ratio (200,000 ppm WPS)			
Discharge temperature at release point (deg C)	18 deg C			
Discharge Depth (m)	**Above sea-floor**		**Below sea surface**	
	-		15	
Diameter of outlet opening (m)	0.50			
Orientation of outlet opening	Vertical , down			
Weight of Cuttings Discharged (MT)	489.52			
Volume Mud Discharged (M3)	71.86			
Weight Mud Discharged (MT)	91.26			
Composition	**[kg/m3]**	**[ppb]**	**MT**	**Comments**
Synthetic Base Oil (Base Fluid)	475.24	166.6	34.148	
Calcium Chloride (Brine Weighting Chemical)	68.62	24.1	4.930	
Lime (pH control)	7.77	2.7	0.558	
Acrylate co-polymer (Fluid loss control agent)	1.29	0.5	0.093	
Fatty acid derivative (Rheology modifier)	3.24	1.1	0.233	
Primary Emulsifier	23.30	8.2	1.674	
Organophylic Clay (Viscosifier)	5.18	1.8	0.372	
Organophylic Supreme Clay (Viscosifier)	2.59	0.9	0.186	
Polymeric Rheology Modifier	2.59	0.9	0.186	
Secondary Emulsifier (Wetting agent)	5.19	1.8	0.373	
Barite (Weighting Agent)	483.04	169.3	34.709	
Total Chemicals Discharged			**77.464**	

Table A4 - Section 4

SECTION 4				
Drilling Fluid Formulation 14 3/4" x 17 1/2" Hole				
Bit Diameter (ins)	17.50	**Section Length (m)**		1,100
Wellbore Washout (Volume %)	12%	**Drilling Rate (m/hr)**		6.97
Mud Density	**SG**	**[ppg]**	**Start of Discharge (time since previous discharge stopped, days)**	10.41
	1.53	12.73		
Mud Type (WBM/OBM/SBM)	SBM			
Mud Description	Assume Average 75/25 o/w ratio (200,000 ppm WPS)			
Discharge temperature at release point (deg C)	18 deg C			
Discharge Depth (m)	**Above sea-floor**		**Below sea surface**	
	-		15	
Diameter of outlet opening (m)	0.50			
Orientation of outlet opening	Vertical , down			
Weight of Cuttings Discharged (MT)	438.74			
Volume Mud Discharged (M3)	65.99			
Weight Mud Discharged (MT)	100.63			
Composition	**[kg/m3]**	**[ppb]**	**MT**	**Comments**
Synthetic Base Oil (Base Fluid)	457.37	160.3	30.181	
Calcium Chloride (Brine Weighting Chemical)	66.04	23.1	4.358	
Lime (pH control)	7.48	2.6	0.493	
Acrylate co-polymer (Fluid loss control agent)	1.25	0.4	0.082	
Fatty acid derivative (Rheology modifier)	3.11	1.1	0.206	
Primary Emulsifier	22.43	7.9	1.480	
Organophylic Clay (Viscosifier)	4.98	1.7	0.329	
Organophylic Supreme Clay (Viscosifier)	2.49	0.9	0.164	
Polymeric Rheology Modifier	2.49	0.9	0.164	
Secondary Emulsifier (Wetting agent)	4.98	1.7	0.329	
Barite (Weighting Agent)	770.31	270.0	50.831	
Total Chemicals Discharged			**88.617**	

Table A5 - Section 5

SECTION 5				
Drilling Fluid Formulation 10 5/8" x 12 1/4" Hole				
Bit Diameter (ins)	12.25	**Section Length (m)**		2,250
Wellbore Washout (Volume %)	13%	**Drilling Rate (m/hr)**		5.21
Mud Density	**SG**	**[ppg]**	**Start of Discharge (time since previous discharge stopped, days)**	7.34
	1.79	14.90		
Mud Type (WBM/OBM/SBM)	SBM			
Mud Description	Assume Average 75/25 o/w ratio (200,000 ppm WPS)			
Discharge temperature at release point (deg C)	18 deg C			
Discharge Depth (m)	**Above sea-floor**		**Below sea surface**	
	-		15	
Diameter of outlet opening (m)	0.50			
Orientation of outlet opening	Vertical , down			
Weight of Cuttings Discharged (MT)	462.41			
Volume Mud Discharged (M^3)	71.59			
Weight Mud Discharged (MT)	127.80			
Composition	**[kg/m3]**	**[ppb]**	**MT**	**Comments**
Synthetic Base Oil (Base Fluid)	412.91	144.7	29.562	
Calcium Chloride (Brine Weighting Chemical)	59.62	20.9	4.268	
Lime (pH control)	6.75	2.4	0.483	
Acrylate co-polymer (Fluid loss control agent)	1.12	0.4	0.081	
Fatty acid derivative (Rheology modifier)	2.81	1.0	0.201	
Primary Emulsifier	20.25	7.1	1.450	
Organophylic Clay (Viscosifier)	4.50	1.6	0.322	
Organophylic Supreme Clay (Viscosifier)	2.25	0.8	0.161	
Polymeric Rheology Modifier	2.25	0.8	0.161	
Secondary Emulsifier (Wetting agent)	4.50	1.6	0.322	
Barite (Weighting Agent)	1101.26	386.0	78.845	
Total Chemicals Discharged			**115.856**	

Table A6 - Section 6

<table>
<tr><td colspan="5">SECTION 6</td></tr>
<tr><td colspan="5">Drilling Fluid Formulation 8 1/2" Hole</td></tr>
<tr><td>Bit Diameter (ins)</td><td>8.50</td><td colspan="2">Section Length (m)</td><td>250</td></tr>
<tr><td>Wellbore Washout (Volume %)</td><td>12%</td><td colspan="2">Drilling Rate (m/hr)</td><td>0.84</td></tr>
<tr><td rowspan="2">Mud Density</td><td>SG</td><td>[ppg]</td><td rowspan="2">Start of Discharge (time since previous discharge stopped, days)</td><td rowspan="2">10.47</td></tr>
<tr><td>1.89</td><td>15.79</td></tr>
<tr><td>Mud Type (WBM/OBM/SBM)</td><td colspan="4">SBM</td></tr>
<tr><td>Mud Description</td><td colspan="4">Assume Average 75/25 o/w ratio (200,000 ppm WPS)</td></tr>
<tr><td>Discharge temperature at release point (deg C)</td><td colspan="4">18 deg C</td></tr>
<tr><td rowspan="2">Discharge Depth (m)</td><td colspan="2">Above sea-floor</td><td colspan="2">Below sea surface</td></tr>
<tr><td colspan="2">-</td><td colspan="2">15</td></tr>
<tr><td>Diameter of outlet opening (m)</td><td colspan="4">0.25</td></tr>
<tr><td>Orientation of outlet opening</td><td colspan="4">Vertical , down</td></tr>
<tr><td>Weight of Cuttings Discharged (MT)</td><td colspan="4">25.65</td></tr>
<tr><td>Volume Mud Discharged (M^3)</td><td colspan="4">4.30</td></tr>
<tr><td>Weight Mud Discharged (MT)</td><td colspan="4">8.14</td></tr>
<tr><td>Composition</td><td>[kg/m3]</td><td>[ppb]</td><td>MT</td><td>Comments</td></tr>
<tr><td>Synthetic Base Oil (Base Fluid)</td><td>394.67</td><td>138.3</td><td>1.698</td><td></td></tr>
<tr><td>Calcium Chloride (Brine Weighting Chemical)</td><td>56.98</td><td>20.0</td><td>0.245</td><td></td></tr>
<tr><td>Lime (pH control)</td><td>6.45</td><td>2.3</td><td>0.028</td><td></td></tr>
<tr><td>Acrylate co-polymer (Fluid loss control agent)</td><td>1.08</td><td>0.4</td><td>0.005</td><td></td></tr>
<tr><td>Fatty acid derivative (Rheology modifier)</td><td>2.69</td><td>0.9</td><td>0.012</td><td></td></tr>
<tr><td>Primary Emulsifier</td><td>19.35</td><td>6.8</td><td>0.083</td><td></td></tr>
<tr><td>Organophylic Clay (Viscosifier)</td><td>4.30</td><td>1.5</td><td>0.019</td><td></td></tr>
<tr><td>Organophylic Supreme Clay (Viscosifier)</td><td>2.15</td><td>0.8</td><td>0.009</td><td></td></tr>
<tr><td>Polymeric Rheology Modifier</td><td>2.15</td><td>0.8</td><td>0.009</td><td></td></tr>
<tr><td>Secondary Emulsifier (Wetting agent)</td><td>4.30</td><td>1.5</td><td>0.019</td><td></td></tr>
<tr><td>Barite (Weighting Agent)</td><td>1238.21</td><td>434.0</td><td>5.329</td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="3">Total Chemicals Discharged</td><td>7.455</td><td></td></tr>
</table>